Combustion

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

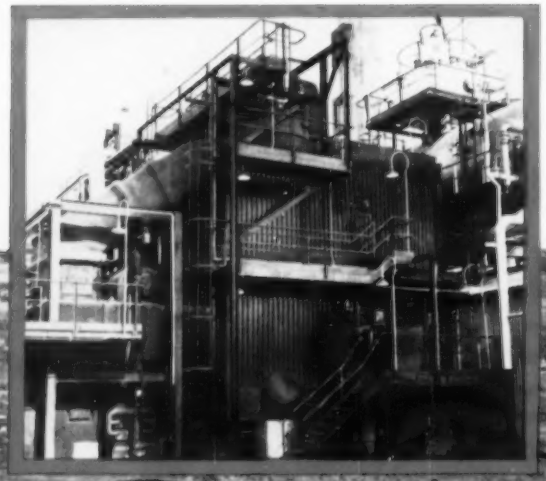
April 1960

A Cure For Oil Corrosion and Slagging

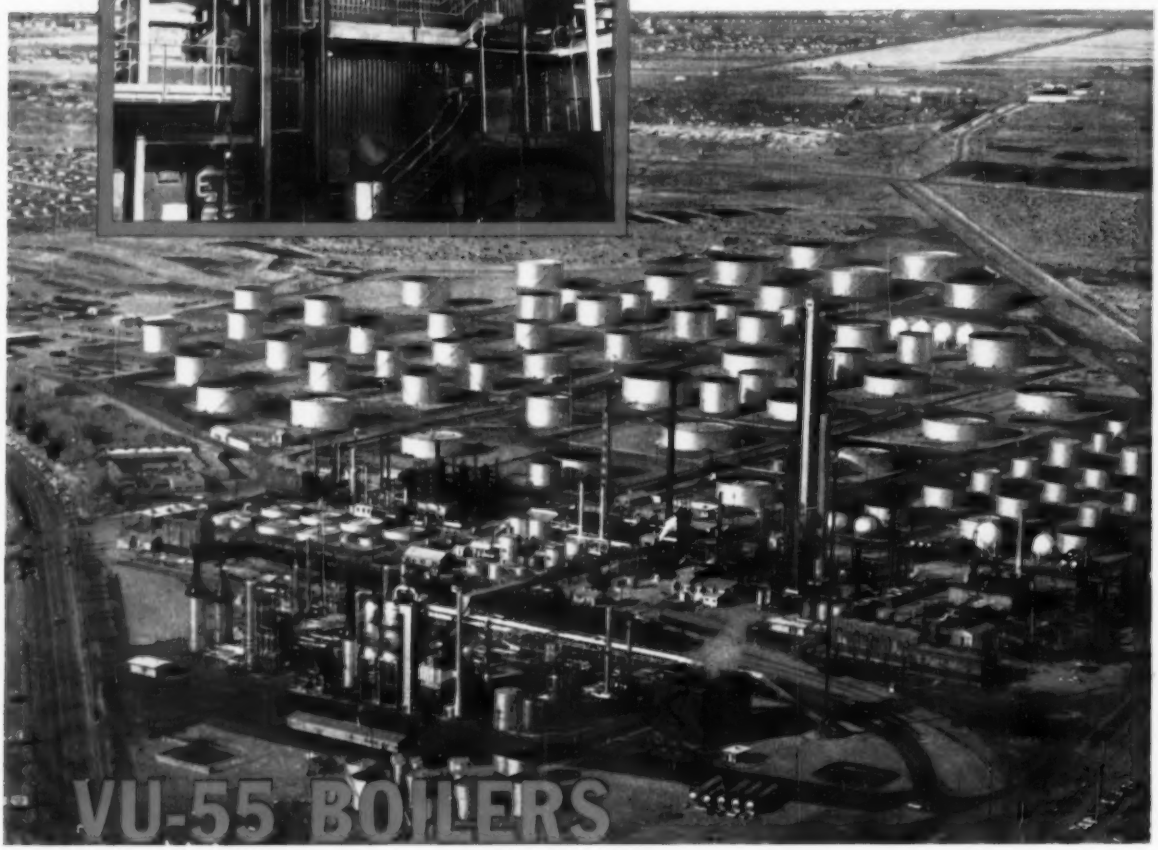
Boiler Flame Failure Forum

Testing Air Preheaters

Coal-Fired Gas Turbine Project



One of the two identical C-E Vertical-Unit Boilers, Type VU-55, installed at the El Paso Refinery of Standard Oil Co. of Texas. These "outdoor" type units are designed for a continuous capacity of 80,000 lb of steam per hr at 400 psi and 550 F. They are designed for pressurized firing and are fitted with tangential burners for the most efficient utilization of oil and gas.



Handle Load Swings Smoothly

...chosen for dependability

In 1955, the Standard Oil Company of Texas made a substantial addition to steam generating facilities at its El Paso Refinery. It placed in service two C-E Vertical-Unit Boilers, Type VU-55.

These units have proved to be the keystone of the refinery's steam supply as they were soon recognized for their exceptional ability to handle load swings and to meet overload demands smoothly and efficiently.

There are several other boilers at the El Paso Refinery, including two other C-E units of smaller size, but the VU-55's have established the best record for reliability and ease of operation. As a matter of fact, the VU-55 Boiler, especially designed for use with oil or gas fuel, is making a consistently good record in numerous installations both in this country and abroad. So – when you are in the market for a new boiler – oil or gas fired – in a capacity range from 70,000 to 150,000 lb of steam per hr – investigate Combustion's VU-55.

COMBUSTION ENGINEERING

Combustion Engineering Building, 200 Madison Avenue, New York 16, N. Y. **Canada: Combustion Engineering-Superheater Ltd.** C-265

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT: NUCLEAR REACTORS; PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE

Combustion

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

volume 31 number 10 **April 1960**

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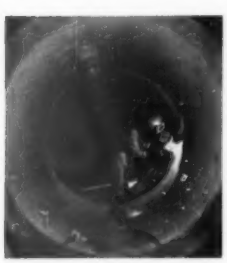
Printed in U. S. A.

The process of turning out a boiler drum for today's units requires both individual trade skills as well as heavy duty equipment.



Boiler Problems Associated With Use of Bunker C Fuel . . . 42
Dr. John J. McMullen

The marine boiler has problems of its own with Bunker C oils. Here the problems are cited and suggestion for minimizing them advanced.

Water Wash of Bunker C Retards Boiler Slag on Atlantic Tanker . . . 43
W. A. Walls and W. S. Proctor

One very different solution to the problems cited in the above article has resulted from the washing procedure described here.

Combustion Engineering Industrial Power Forum—Conference I; Flame Sensing, Flame Failure, Purging . . . 50

The often grumbled complaints and the counter claims of performance achievements for flame sensing, flame failure controls and sensible limits for purging is bandied about by a panel of experts.

Testing The Rotary Regenerative Air Heater—Part II . . . 60
Joseph Waitkus

Concluding part of a series on air preheaters in which the emphasis is directed towards temperature measurement problems.

Bureau of Mines Coal-Fired Gas Turbine Project . . . 67
James P. McGee and R. C. Corey

The recently abandoned Locomotive Development Committee's study of the basic gas turbine in coal-fired applications has been taken up and renewed by the Bureau of Mines.

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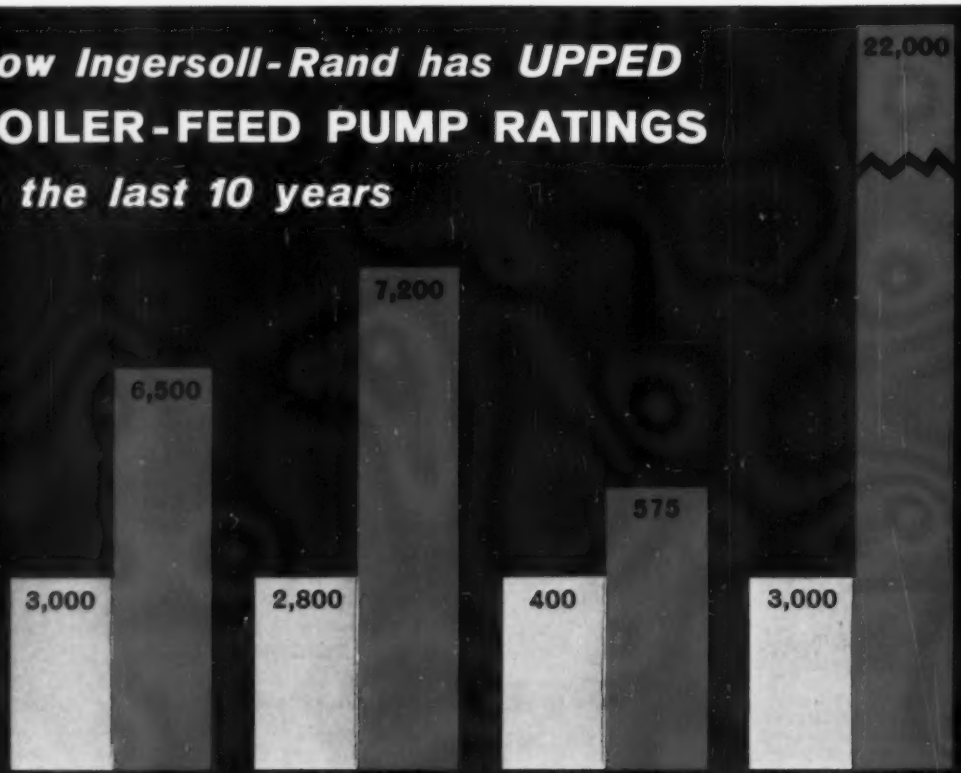
How Ingersoll-Rand has UPPED
BOILER-FEED PUMP RATINGS
in the last 10 years

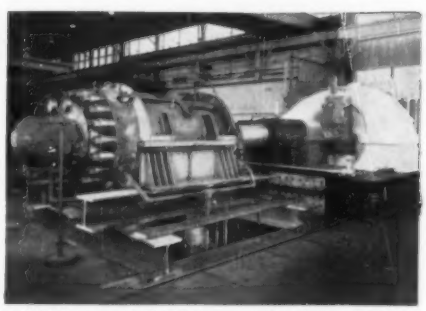


. . . to help power companies produce more kilowatts with better efficiency

In this chart of pump progress, none of the figures are theoretical. They are actual performance ratings of I-R boiler-feed pumps installed or now on order.*

The progress to higher and higher pump ratings has been made possible by improved design engineering, better metallurgy, improved manufacturing methods and advanced hydraulic research. To the user, it means simpler installations with fewer pumps to do a given job—higher operating efficiencies—better heat rates—improved steam plant performance and economy.

Combine this record of pump *progress* with Ingersoll-Rand's traditional *dependability*, and you'll see why Ingersoll-Rand is clearly recognized as the world's leading manufacturer of boiler-feed pumps. In short, this is why it always pays to discuss your pump requirements with Ingersoll-Rand.



11,000 horsepower boiler-feed pump undergoing performance tests in Ingersoll-Rand's new testing department. Pump is capable of handling 3600 gallons of feed water per minute at 4550 psig discharge.

**The figures shown do not represent limits of I-R boiler-feed pumps. If your particular application falls outside of the ranges shown, we would welcome the opportunity to discuss it with you.*

A CENTURY 1860 – 1960 *OF PUMP PROGRESS*

Ingersoll-Rand

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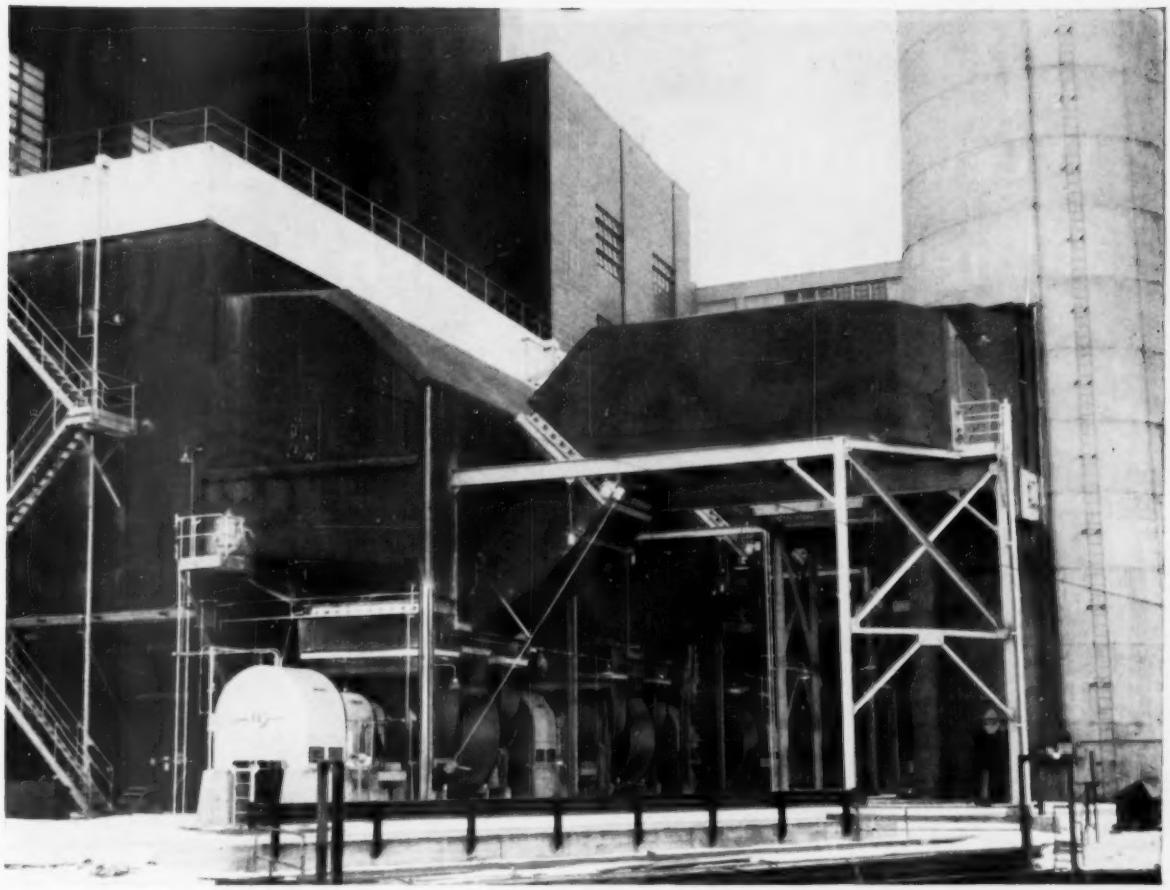
COMPRESSORS • GAS & DIESEL ENGINES • PUMPS • AIR & ELECTRIC TOOLS • CONDENSERS • VACUUM EQUIPMENT • ROCK DRILLS



"Buffalo" Induced Draft Fans at Commonwealth Edison Company's Waukegan Station, Unit 7. Fans draw from a common precipitator plenum chamber and discharge into a common stack. Fans deliver 312,000 cfm at 21" S.P. at 300° F., have air cooled bearings. Engineered by Sargent and Lundy.

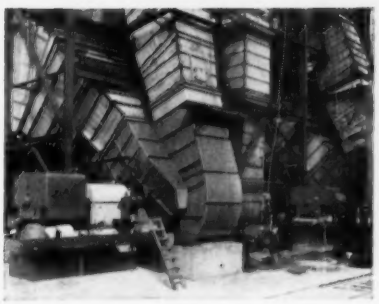
COMMONWEALTH EDISON COMPANY SELECTS "BUFFALO" FOR INDUCED DRAFT

The Commonwealth Edison Company has, over the years, purchased numerous "Buffalo" fans. This is a tribute to the performance, quality and long service life of "Buffalo" Products.

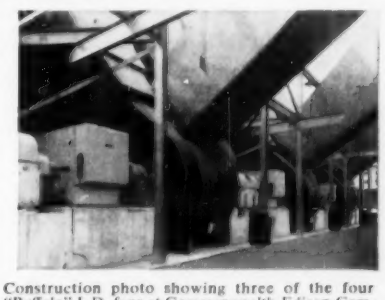
This same reliable performance and "Q" Factor Quality Construction is available to you in every "Buffalo" fan.

You are assured of getting the right fan for every job, too, since "Buffalo" offers a complete line of fan wheel types, each suited to a different set of circumstances.

The next time you need fans for any installation, large or small, be sure to phone your "Buffalo" Engineering Representative. He will have the best fan for the job and the experience necessary to see that it is recommended.



Installation photo, Commonwealth Edison Company's Will County Station Unit 3. This is one of four I. D. Fans now operating at 237,500 cfm at 15" S.P., 300° F. Engineered by Stone and Webster Engineering Corp.

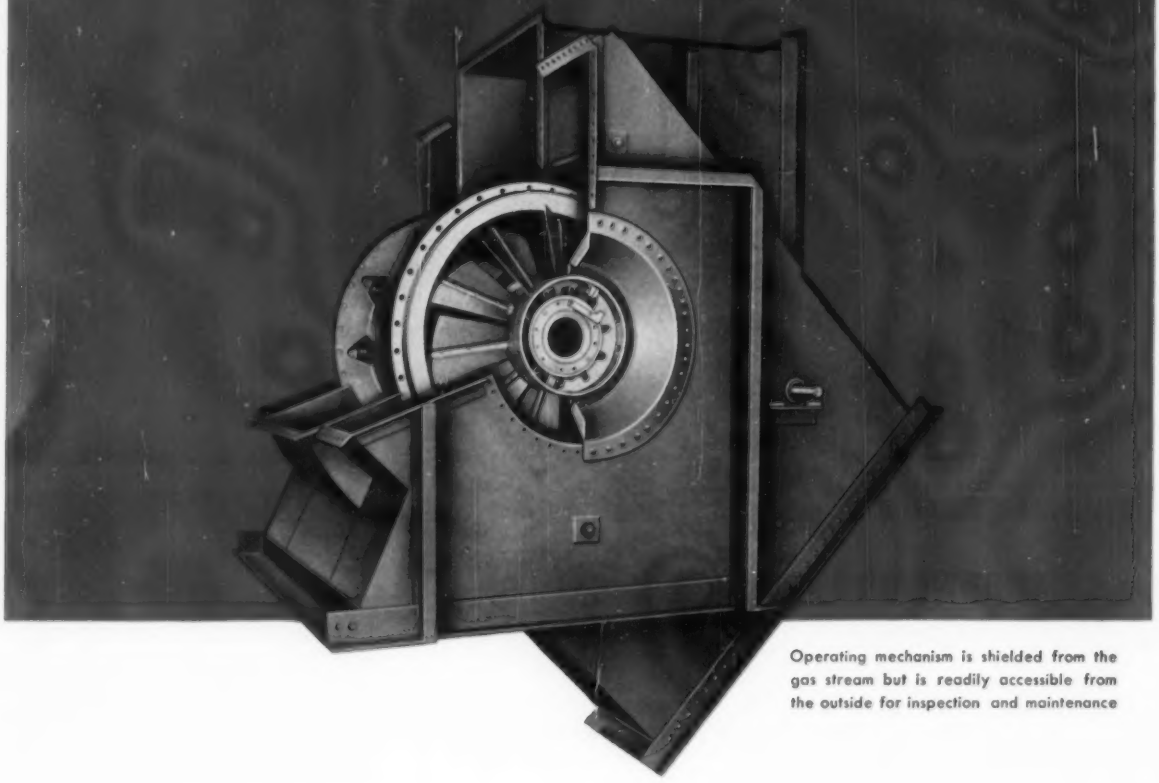


Construction photo showing three of the four "Buffalo" I. D. fans at Commonwealth Edison Company's Fisk Street Station. These fans are now each operating at 362,300 cfm at 23.2" S.P., 325° F. Engineered by Bechtel Corp.

BUFFALO FORGE COMPANY
Buffalo, N. Y.
Buffalo Pumps Division Buffalo, N. Y.
Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

VENTILATING • AIR CLEANING • AIR TEMPERING • INDUCED DRAFT • EXHAUSTING
FORCED DRAFT • COOLING • HEATING • PRESSURE BLOWING

Westinghouse Volume Control helps pay off fly ash dust control investments



Operating mechanism is shielded from the gas stream but is readily accessible from the outside for inspection and maintenance

Westinghouse inlet vane air spin control is a *proven* low cost method of regulating Induced Draft fan output when using dust arrestors.

Many major power producers are using Westinghouse Inlet VANE CONTROL® on coal-fired induced draft fan applications, paying off their investment in dust control. Ask your Sturtevant Division Sales Engineer for a list of their names and installations — or, write Westinghouse Electric Corporation, Hyde Park, Boston 36, Mass.

PLANTS AT HYDE PARK, MASS., LA SALLE, ILL., BERKELEY, CALIF.

YOU CAN BE SURE... IF IT'S Westinghouse

Watch "Westinghouse Lucille Ball-Desi Arnaz Shows" CBS-TV-Fridays

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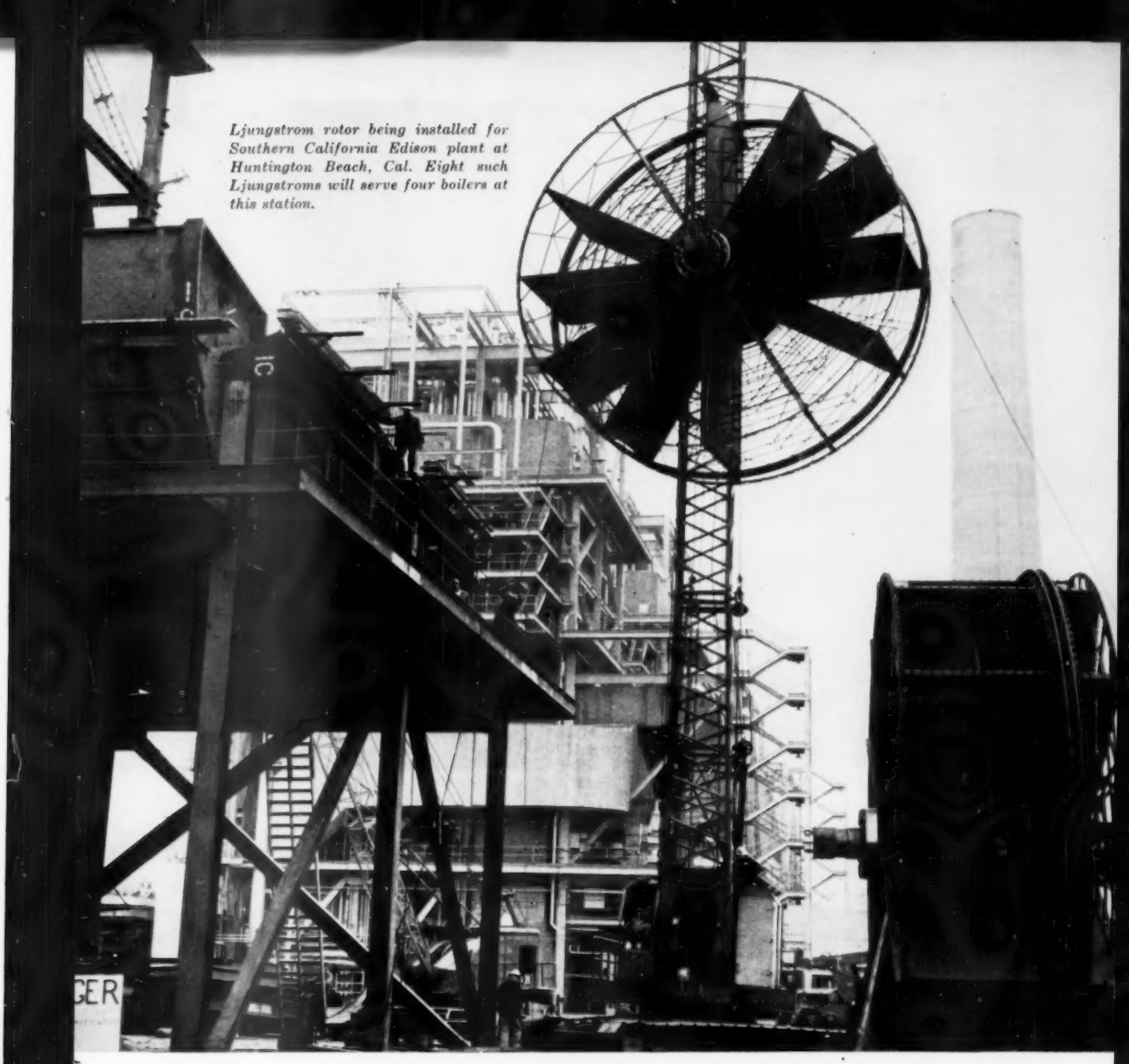


Ljungstrom rotor being installed for Southern California Edison plant at Huntington Beach, Cal. Eight such Ljungstroms will serve four boilers at this station.

AIR PREHEATER SERVICE WILL STILL BE IN EFFECT ON THESE UNITS IN THE YEAR 2000

These new Ljungstrom® Air Preheaters, being installed at Southern California Edison's Huntington Beach Station, will be protected by an unusual service policy, one that guarantees regular inspection by Air Preheater engineers throughout the life of each unit.

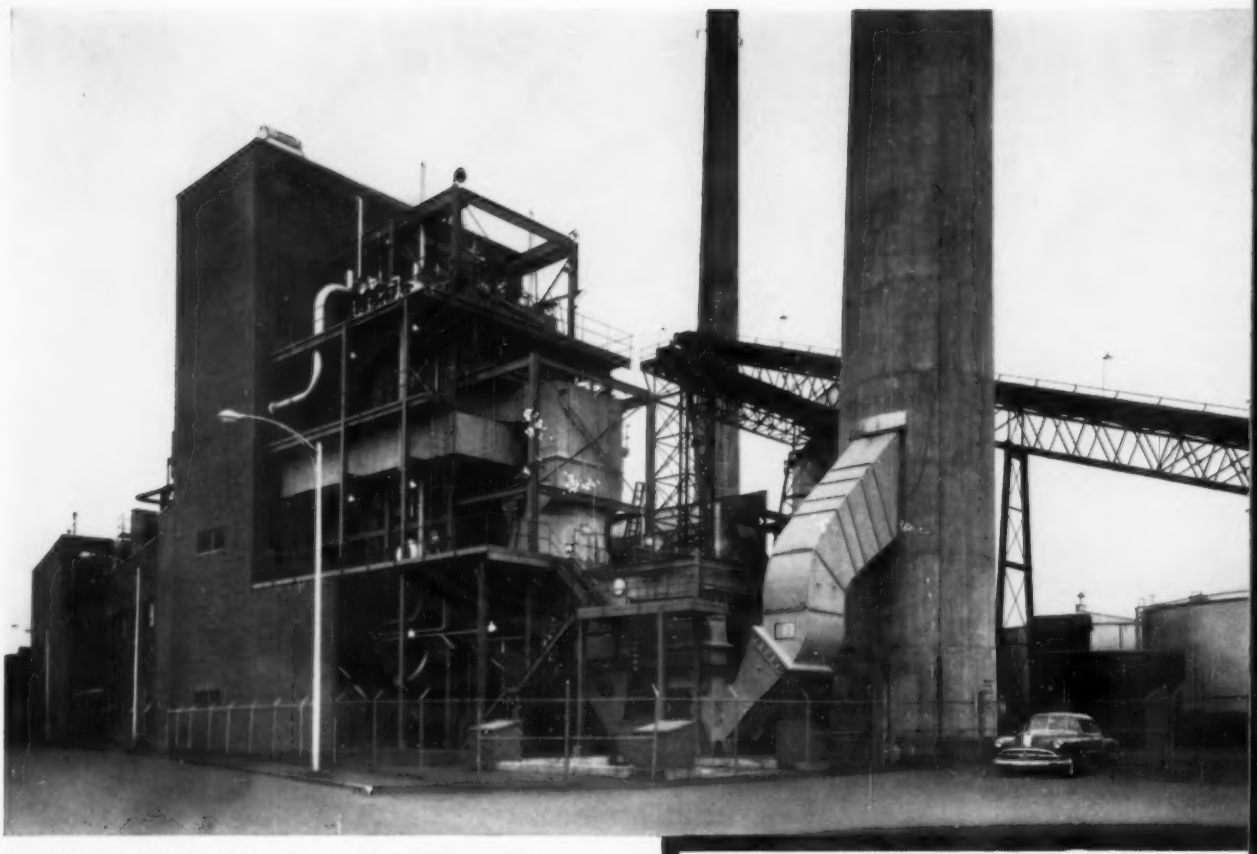
There's no terminal date on this service — it's in effect as long as the units are in operation. In fact, Lifetime Air Preheater Service is still helping to keep the first Ljungstrom installation in the U.S. running perfectly, although it's been in operation almost 40 years.

Air Preheater provides first-rate *factory* service too, In one instance, in response to a last-minute decision to replace cold-end elements near the end of a scheduled shutdown, Air Preheater *fabricated and shipped* over 13,000 pounds of heating elements the day after the order was received.

Regular inspection and fast factory service are just two of the advantages Air Preheater offers its customers. Another is expert knowledge of boiler and preheater problems, gained through 35 years' experience. This combination—knowledge of customer problems and a *continuing* interest in them — probably explains why nine out of ten preheaters sold today are Ljungstroms.

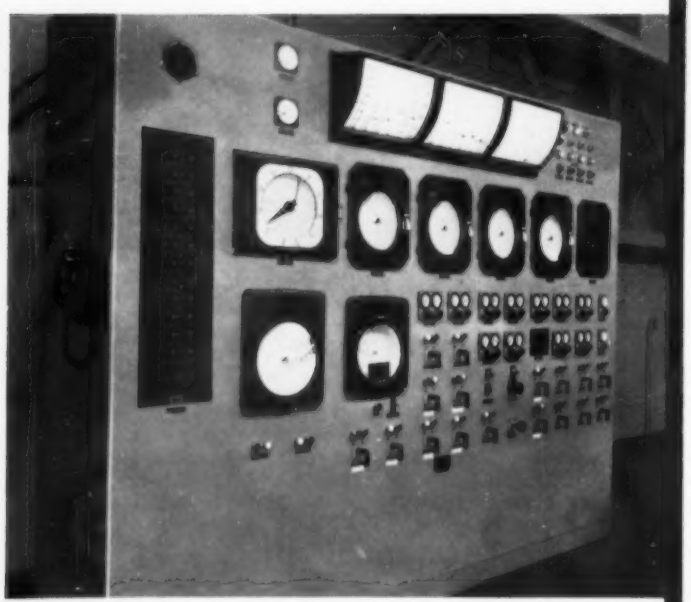
THE AIR PREHEATER CORPORATION

60 East 42nd Street, New York 17, N. Y.

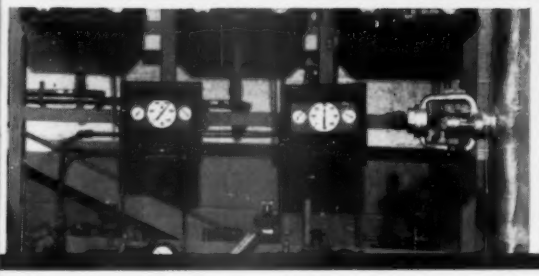


Except for the firing aisle and control room, Boiler Unit 7 is outdoors and subject to sub-zero temperatures. The unit delivers steam at 850 psig and 900°F to a 16,500-kw turbine-generator installed in the tall building (left) some 200 feet away.

Copes-Vulcan boiler control automatically balances output with demand at Taunton Plant



Eleven miniature Copes-Vulcan stations on this operating panel provide remote control of all processes with automatic-to-manual, or manual-to-automatic selection, with "bumpless" transfer. Automatic and manual loadings can be matched perfectly without going through a seal or reset position.



Diaphragm-type control valve (upper left) is used with Copes Type 3-L feedwater control. The valve features positioner, air lock, and side-mounted handwheel for emergency operation.

Designed for superior accuracy and long range dependability, Copes-Vulcan valves establish new standards of efficiency for pressure, temperature, flow, and level control.

Two versatile regulator valves are available for pressure standards from 125 through 2500 pounds. Diaphragm-type CV-D is designed for remote control service, can be direct or reverse acting, features excellent rangeability. Piston-type CV-P is designed for high-duty service, assures maximum power with precise positioning. **Write for Bulletin 1027.**

The two field mounted Copes-Vulcan indicating pressure transmitters (lower left) are used for feedwater (left) and fuel oil (right). Proportional action with pneumatic feedback is ideal for pressure regulating service.

Copes-Vulcan transmitters feature good repeatability. Standard output pressure is 3 to 15 psi for input bands of 1 to 100%. Outputs of 6 to 30 psi and 12 to 60 psi are also available. **Write for Bulletin 1036.**

Drive unit (right) for the inlet damper of the induced-draft fan is installed at ground level outdoors. Insulation, used for protection against adverse weather, is easily removed for inspection and maintenance of the unit.

Copes-Vulcan Drive Units permit remote positioning by automatic or manual signals. They may have linear, square, or square-root characteristics, or may be field-characterized.

Five models are available. All have 90-degree angular rotation and may be manually operated by a handwheel. **Write for Bulletin 1033.**

The Municipal Lighting Plant in Taunton, Massachusetts, selected Copes-Vulcan to provide Unit 7 with precision boiler control. Featuring simplicity of circuits and dependable accurate components, the Copes-Vulcan system automatically maintains a constant main steam-header pressure under varying demands. Peak loads reach 170,000 pounds per hour. Operation remains under fully automatic control down to 40,000 pounds per hour.

Unique combustion control includes skillfully designed circuits for fuel-loading report-back and fuel cut-back. Other controls assure constant furnace pressure, the correct ratio between steam flow and air flow, and a practically constant drum water level.

Temperatures and pressures regulated. Air-heater temperature, mill pressure, and steam temperature at the superheater outlet are accurately managed.

A complete line—a complete service. In addition to boiler control, the Copes-Vulcan line includes complete systems for fully automatic soot blowing, pressure reducing, and desuperheating. All are custom engineered. All are backed by more than 50 years of design experience.

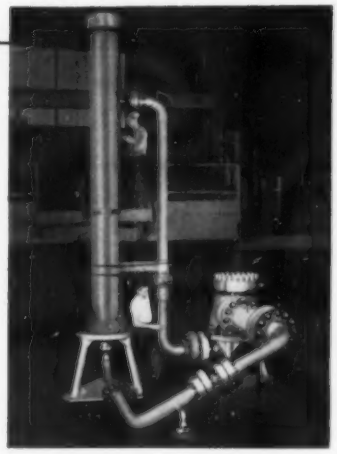
Whether your boiler be large or small, power or process, Copes-Vulcan can provide a unit or a coordinated package to meet your requirements.

For the complete story, write for Bulletin 1065. Copes-Vulcan Division, Erie 4, Pennsylvania.

Copes-Vulcan Division

BLAW-KNOX

ALL IN A DAY'S WORK at *Pittsburgh Piping*



STAINLESS STEEL AUTOCLAVE and VOLUTE
Shop Fabricated

by *Pittsburgh Piping*

This autoclave and volute assembly is typical of the work that goes through Pittsburgh Piping shops. Fabricated of Type 304 Stainless Steel, it is complex in design and is built for high pressure, high temperature service. This type of fabricating is a "natural" for Pittsburgh Piping. We pioneered the application of austenitic steel piping materials for central stations operating at 1050°F. and above, and fabricated the piping for the world's first atomic-powered submarine and central station. Highly specialized methods, machines, and apparatus have been developed and are employed in this work. Use them on your high temperature, high pressure piping jobs.

Promoting Progress ***IN POWER AND PROCESS PIPING***

Pittsburgh Piping **AND EQUIPMENT COMPANY**
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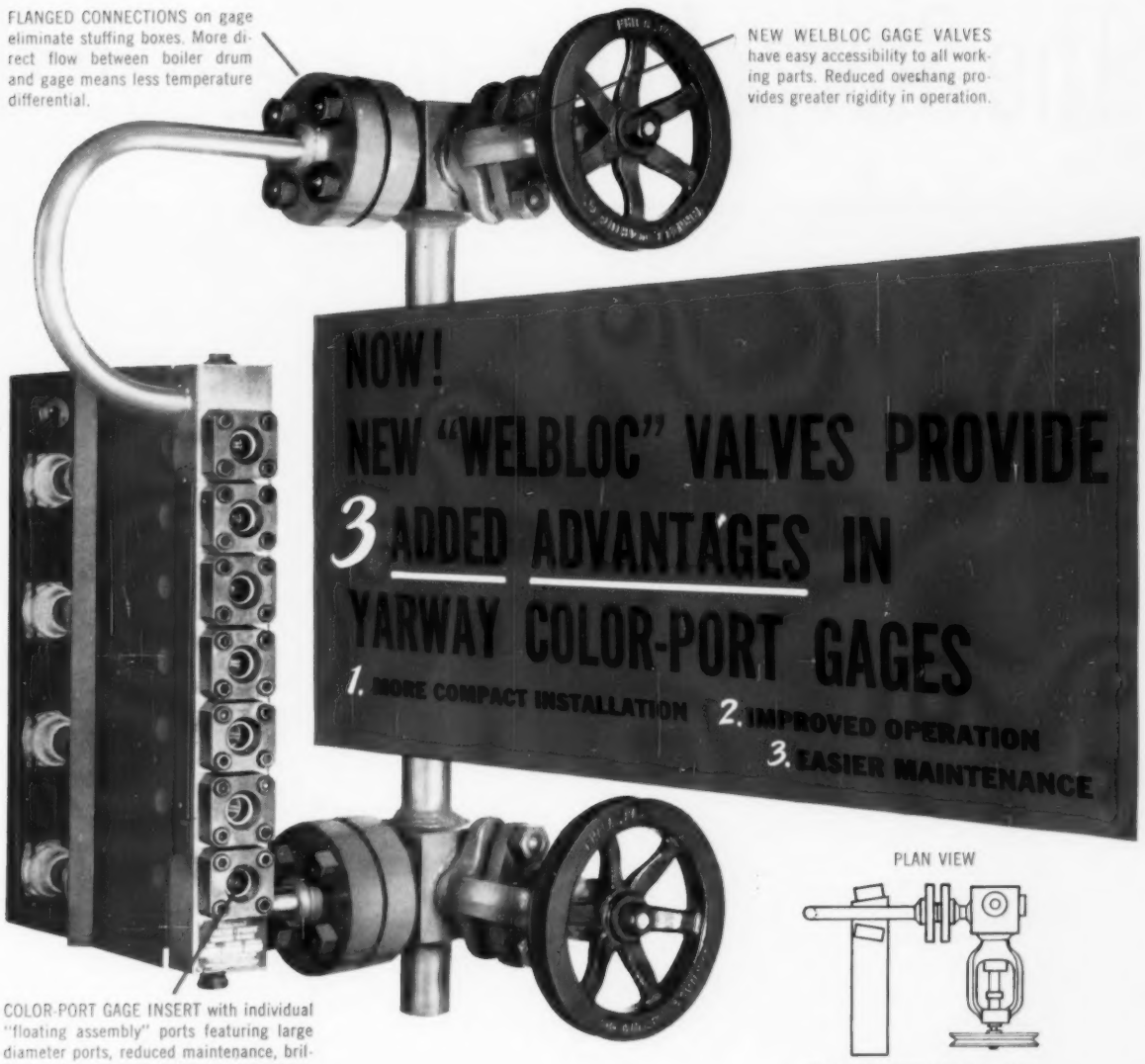
PP-32

FLANGED CONNECTIONS on gage eliminate stuffing boxes. More direct flow between boiler drum and gage means less temperature differential.

NEW WELBLOC GAGE VALVES have easy accessibility to all working parts. Reduced overhang provides greater rigidity in operation.



COLOR-PORT GAGE INSERT with individual "floating assembly" ports featuring large diameter ports, reduced maintenance, brilliant red and green boiler level readings.

PLAN VIEW

MORE COMPACT DESIGN reduces installation space requirements up to 40%. Note: illuminator may be mounted on either face of gage insert.

Yarway's latest improvement in boiler water level gage design—"WELBLOC" GAGE VALVES—gives you these new advantages:

SIMPLIFIED INSTALLATION—Close-coupled design reduces space requirements by 40% in the viewing axis of the gage. Whole unit weighs less, is easier to handle.

IMPROVED OPERATION—Greater rigidity when operating handwheels, because of reduced overhang. More direct flow of boiler water to gage, resulting in reduced temperature differential of insert.

EASIER MAINTENANCE—Single drain connection serves both gage and circulating tie-bar.

Couple these *3 new advantages* with the well-known standard COLOR-PORT features:

- **brilliant red and green readings**
- **increased operational time**
- **reduced maintenance costs**
- **easy method of washing out gage**

COLOR-PORT gives you the best buy in medium and high pressure water gages today. Write for the full YARWAY COLOR-PORT story.

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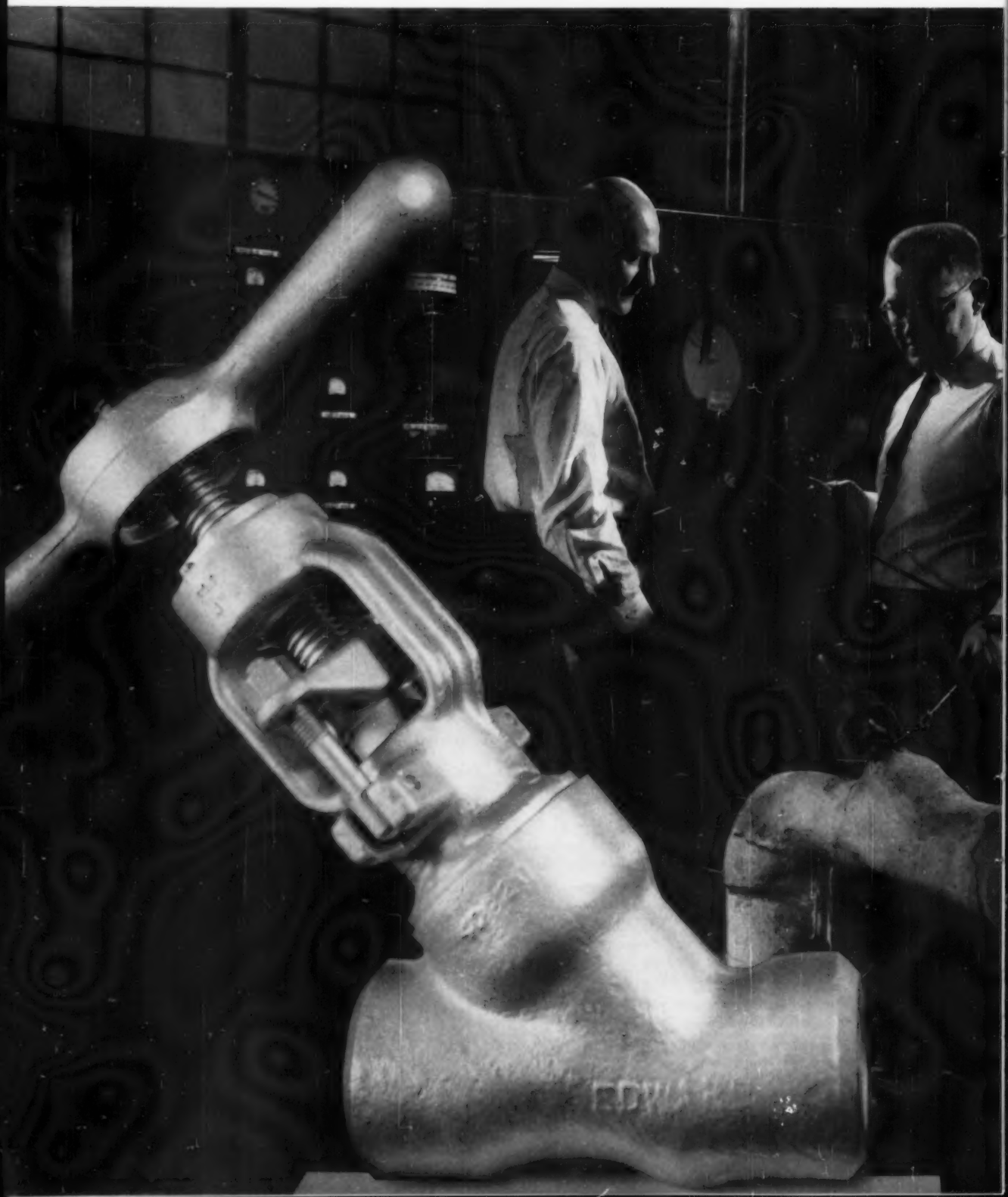
BRANCH OFFICES IN PRINCIPAL CITIES

YARWAY
A MARK OF QUALITY IN STEAM ENGINEERING

The Story of Edward Research



and the Leak-proof Valve

In the early 1940's, the advance of steam power plant pressures and temperatures demanded a leak-proof, small sized valve—one with permanent tightness at the seat joint and one which would solve the failures of mechanical gasketed bonnet joints under elevated temperatures. The story behind the development of the Edward leak-proof Univalve* (sizes to 2½" in 1500, 2500 and 4500 lb. pressure classes) is the story of the product research that solved this industry problem.

EARLY EXPERIMENTING: Elimination of the bonnet joint entirely, by providing a one piece body-yoke construction, appeared to be a logical approach to the bonnet joint problem. But this created a new problem—how to apply and *how to service* an integral Stellited seat from a distant point at the top of the valve yoke. Some valve manufacturers chose to split the valve body near the seat and then reassemble the body with a full pressure weld. Others chose a full pressure weld at the normal bonnet joint position. Neither approach allowed the user to disassemble the valve and both approaches resulted in the sacrifice of a positive, permanent backseat—a desirable feature in any high-pressure valve. Edward engineers refused to make these concessions.

ENGINEERS FIND SOLUTION: After many attempts, Edward engineers developed a water-cooled welding torch for the application of the Stellite seat. This provided a stress-free Stellite layer of uniform density, firmly bonded to the body, free of cracks and pin hole porosity. Simultaneously, other Edward engineers sought the answer to the bonnet joint leakage problem. Extensive research and testing of a variety of body-bonnet combinations and seal-welding techniques resulted in the four elements of today's proven Univalve bonnet joint—a body-bonnet shoulder, load carrying thread, guiding section for alignment and the seal weld.

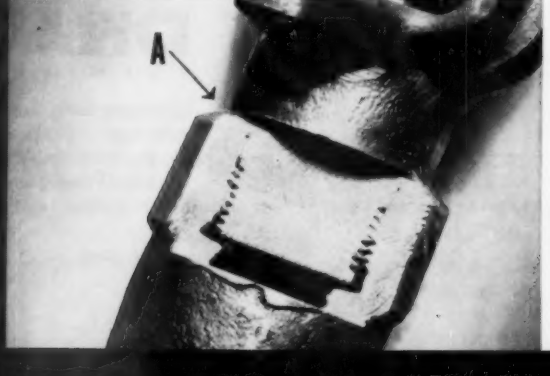
NEW DESIGN PROVES OUT: Months of research testing failed to find a weakness in the new design. Thousands of operations at rated pressure and temperature indicated long-time seat tightness superior to anything previously achieved. Bonnet joint design could not be made to fail at several times the valve rating. Tests were conducted with supercritical steam pressures up to 6000 psi at 1050 F in the only known facilities capable of producing those conditions at that time. And, to date, *hundreds of thousands of Univalves are in service with only one recorded instance of bonnet joint leakage*—a minor defect in the seal weld.

Edward builds a complete line of forged and cast steel valves from ⅛" to 18", in globe and angle stop, gate, non-return, check, blow-off, stop-check, relief, hydraulic, instrument, gage and special designs for pressures up to 10,000 lbs. For more detailed information, contact your Edward Representative, or write Edward Valves, Inc., 1206 West 145th Street, East Chicago, Indiana. Subsidiary of Rockwell Manufacturing Company. Represented in Canada by Lytle Engineering Specialties, Ltd., 438 St. Peter Street, Montreal.

EDWARD STEEL VALVES
another fine product by
ROCKWELL

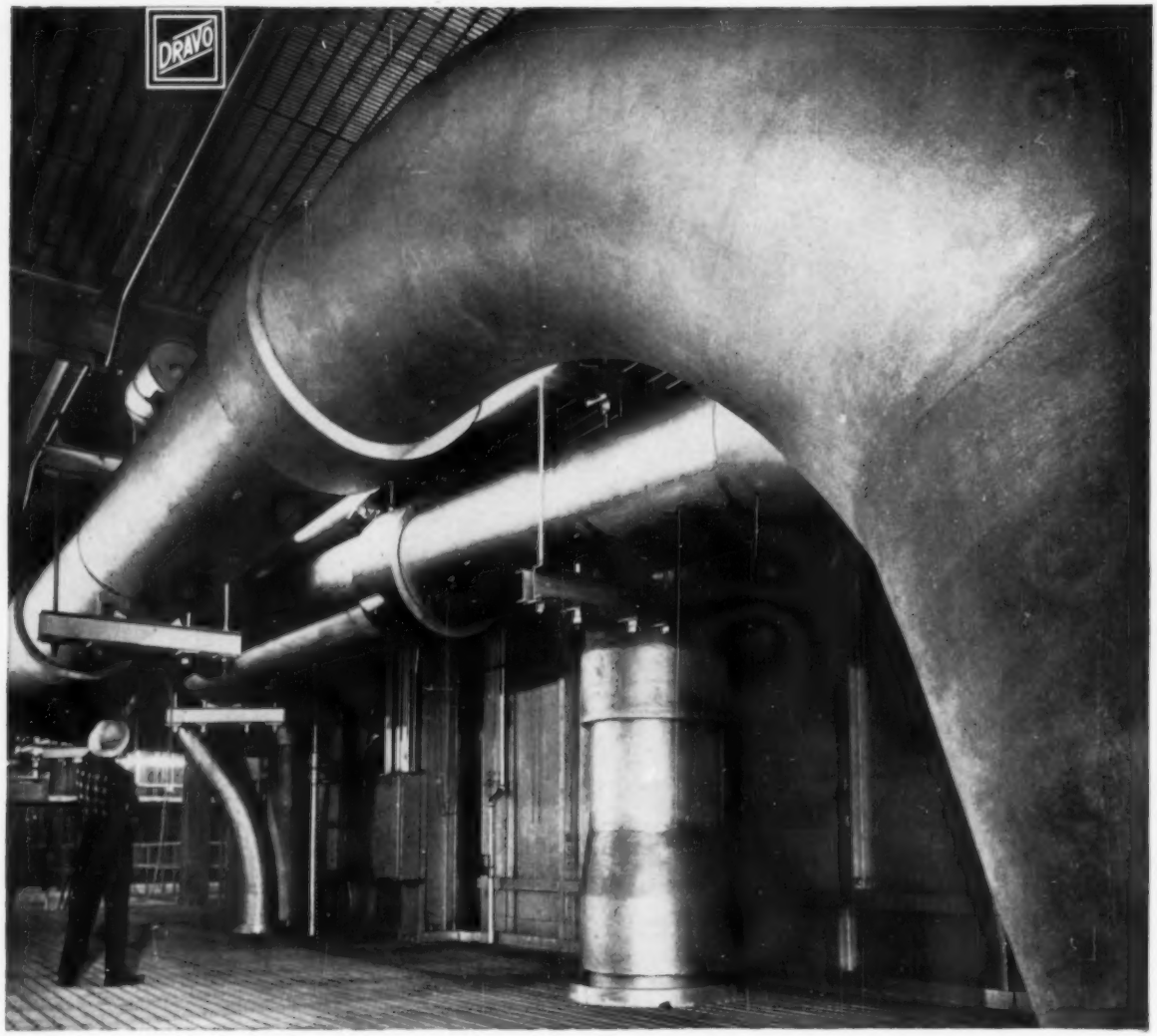
◀ **E. A. STICHA,** Chief Research Metallurgist, and R. K. Wagenblast, Research Engineer, measure temperature of valve seal weld in superheater test loop used in Univalve research.

▼ **DESTRUCTION TESTS IN EDWARD LABORATORIES IN EARLY 1940's**—Bonnet seal weld (A) of test valve cracked only after body creep occurred at 200° F above primary temperature and four times the primary pressure.



CRITICAL LEAKAGE PROBLEMS ATTACKED BY EDWARD RESEARCH ENGINEERS—(A) Bonnet leakage solved by design featuring threaded structural joint and seal weld; (B) Seat leakage solved by revolutionary Stellite seat welding technique.

*T.M. Reg. U.S. Pat. Off.



Three-inch wall main steam piping. Boiler will operate at 2400 pounds per square inch and 1050° Fahrenheit.

Race track for 227,000 horses

At Ohio Edison's new Stratton power station, high pressure, high temperature steam races through this heavy wall piping at 125 miles per hour, creating more than 227,000 horsepower in the turbine.

In addition to main steam and boiler feed lines the project included instrument piping and all auxiliary systems. This is the first of four 170,000 kw units to be installed at the Stratton station; Dravo will fabricate piping for all four.

Inquiries are invited on this or any of the engineered products and services listed below. Write DRAVO CORPORATION, PITTSBURGH 25, PENNSYLVANIA.

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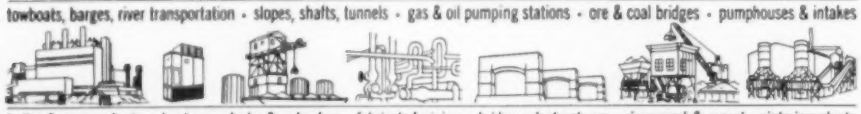


boiler & power plants · heaters · docks & unloaders · fabricated piping · bridge sub-structures · river sand & gravel · sintering plants

DRAVO
CORPORATION

mill lubrication systems · foundations · grating
marine repairs · gantry and floating cranes
mechanical construction · process equipment
locks & dams · vibrating screens & conveyors
ready-mixed concrete · dredging · pile driving

If coal piles like this should ever be exhausted, American Industry would grind to a virtual halt — for coal still provides more "Go Power" than all other fuels combined . . . You can safely rely on Beacon as a dependable source to keep YOUR fuel supply always ahead of need. The 18,000,000 yearly tons we handle include a wide variety of coals with a complete range of properties in any quantity you require. A central control laboratory for combustion studies is supplemented by quality control laboratories at each of our larger mines. Preparation facilities are modern, teletype service connects our sales offices with major mines so that orders can be immediately placed, traced and expedited, and our trained Representatives understand combustion problems, and work their hardest to help you solve them.

BEACON COAL

EASTERN GAS AND FUEL ASSOCIATES

PITTSBURGH • BOSTON • CLEVELAND • DETROIT • NEW YORK
NORFOLK • PHILADELPHIA • SYRACUSE

For New England: New England Coal & Coke Co., For Export: Castner, Curran & Bullitt, Inc.

Replace Complete Trim Without Removing Valve From Line!

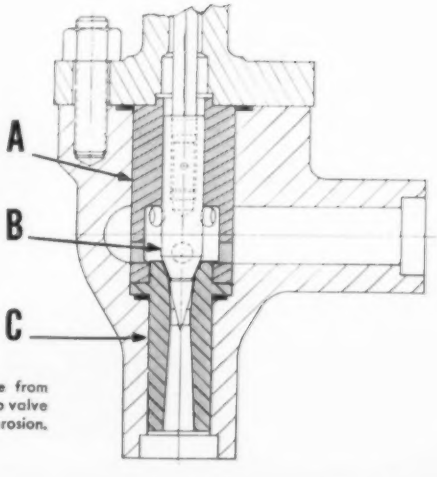
Rockwell-built Republic V-10 valves with Quick-change Trim save many hours of downtime on severe energy conversion applications with pressure drops up to 3500 lbs.

The Republic V-10 angle valve for high-pressure liquid or steam regulating services offers unique valve maintenance advantages because of its Quick-change Trim construction.

Quick-change Trim in the V-10 valve makes it possible for you to replace the valve seat, inner valve and guide in little more time than is required to dismantle and reassemble a bolted joint. No time is required for lapping the seating surfaces of the valve, since this is done in advance. *And you can make this quick trim change in minutes without removing valve from the line.* The savings to you are considerable in downtime and maintenance expense.

Republic V-10 Valves are available with either welded seat or replaceable seat, in addition to the Quick-change Trim design, with bolted or pressure seal bonnets. V-10 valve contours are designed to produce not only the desired regulating characteristics, but also to reduce erosion damage and noise as well. Precise manufacture and long-life materials make Republic regulating valves perform better, last longer, with less maintenance. For additional information, contact your nearest Republic Representative, or write to Republic Flow Meters Company, 2240 Diversey Parkway, Chicago 47, Illinois. In Canada: Republic Flow Meters Canada, Ltd., Toronto. Subsidiary of Rockwell Manufacturing Company.

Rockwell-Republic V-10 regulating valve with Type J-1 positioner is designed for rugged high-pressure liquid or steam service.



Quick-change Trim feature makes it possible to replace the seat guide (A), inner valve (B), and seat (C), without removing valve from the line. Seat extends to valve outlet to prevent body erosion.

REPUBLIC INSTRUMENTS AND CONTROLS
more fine products by
ROCKWELL

The Valley Camp Coal Company provides a complete combustion engineering service for its customers, actual and prospective.

Meeting with a Valley Camp Representative has been the first step to lowered steam costs for many companies . . . . . *How about yours?*

THE VALLEY CAMP COAL COMPANY

Western Reserve Building • Cleveland 13, Ohio

SUBSIDIARIES —
Great Lakes Coal & Dock Co., Milwaukee, Wis. • Great Lakes Coal & Dock Co., St. Paul, Minn. • Fort William Coal Dock Co., Ltd., Fort William, Ont. • The Valley Camp Coal Co. of Canada Ltd., Toronto, Ont. • Kelley's Creek & Northwestern Railroad Co. • Kelley's Creek Barge Line Inc. • Pennsylvania & West Virginia Supply Corp.

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Philadelphia • Baltimore • Buffalo • Pittsburgh • Wheeling • Cleveland • St. Paul • Cincinnati • New York • Milwaukee • Superior, Wis. • Fort William, Ont. • Toronto, Ont.

DAMPNEY COATINGS LIVE WITH IT!

True measure of a high-heat coating's worth is *continuous operation at rated temperature.* Yet many so-called "heat-resistant" coatings take only occasional peaks — fail rapidly in 'round-the-clock service.

Dampney coatings are rated always for day in, day out operation at maximum temperatures. Hold them to it, if schedules call for steady heat, or let them fluctuate to ambient and back. Either way, Dampney silicones and ceramics give you full protection — with plenty in reserve.

Most important, Dampney coatings are selected to meet specific conditions of operation, temperature and corrosive environment. Thus they establish a lasting foundation easily maintained and permanently ending time-consuming and costly surface preparation.

Repeat orders — from a typical customer, 26 in 12 months for enough material to protect 1,929,000 square feet of steel — is the best evidence we have that when industry wants honest high-temperature coatings, it remembers Dampney silicones and ceramics, identified by the two trade names, DAMPNEY and THUR-MA-LOX.

We suggest you do likewise when you want real protection — resistant to 1000°F., to atmospheric corrosion, and to weather exposure — for these industrial hot spots . . .

stacks and breechings	•	turbine interiors
steam lines	•	precipitators
kilns	•	coke ovens
forced and induced draft fans	•	incinerators
heat-treating furnaces	•	pulverizers
autoclaves and retorts	•	blast and open hearth furnaces

Remember, too, the first Dampney trade name and product, known and used today the world around, APEXIOR NUMBER 1 for boiler interiors. For all hot metal, wet or dry, the best protection available is made and marketed by

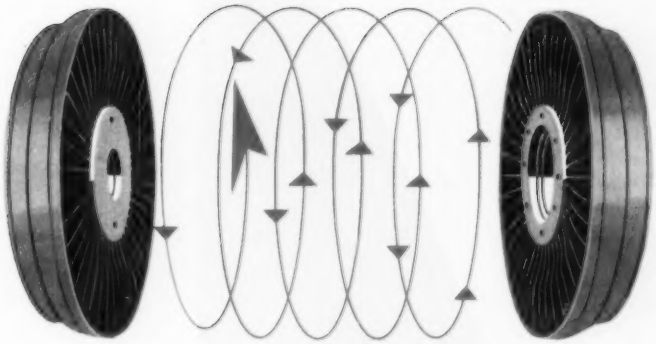
MAINTENANCE FOR METAL

THE DAMPNEY COMPANY

HYDE PARK, BOSTON 36, MASSACHUSETTS

Coatings for all temperatures to high heat— all corrosive environments.

207



New from American-Standard
Industrial Division

Power-Lift† for Power Plants

cuts auxiliary demand with Gýrol® Fluid Drive

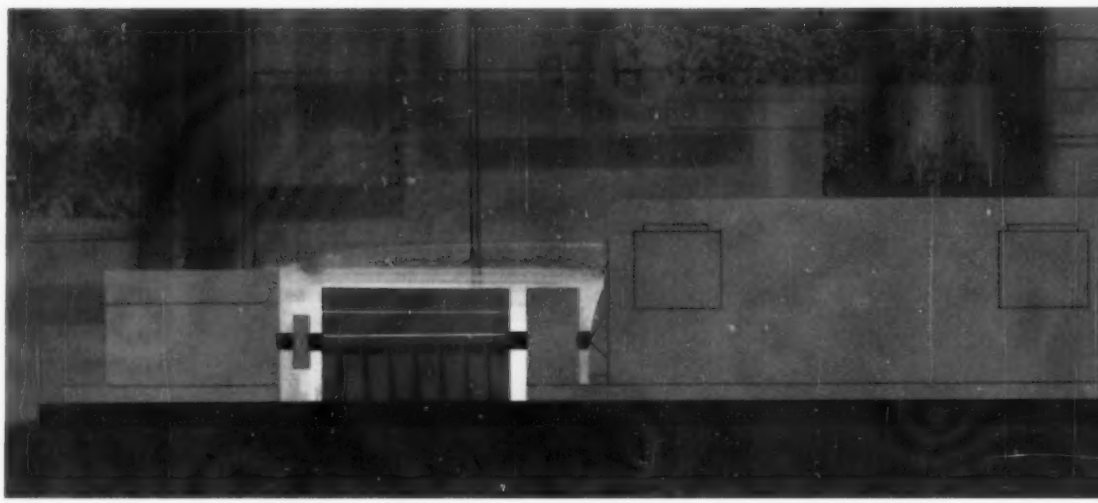
Power-Lift is a timely new concept of coordinated products and services from American-Standard Industrial Division. Its purpose is to help you raise overall efficiency in your plant by offering *products* that are proved in the field and designed, engineered, and manufactured to a uniform standard of quality and performance . . . with *service* by product specialists in every principal city.

← LIFT THE FLAP *and see how Gýrol Fluid Drives provide cost-saving benefits for fans and boiler feed pumps . . .*

†Service-mark of American-Standard

American-Standard Industrial Division POWER-LIFT IN ACTION

Gýrol® Fluid Driv
proved record of



On-the-shaft Fluid Drive applications offer multiple savings. In addition to the well-known savings which adjustable speed offers, main shaft driven pumps eliminate costly electrical accessories necessary for motor driven pumps. Auxiliary demands are reduced, so more power can be released to consumer lines.

"On-the-Shaft" Gýrol Fluid Drives
installed, or to be installed,
for the following public utilities:

Consolidated Edison of New York, Inc.
Public Service Electric & Gas Co.
Pacific Gas & Electric Co.
Louisiana Power & Light Co.
Southern California Edison Co.
Consumers Power Co.
Commonwealth Edison Co.

On moto
advantages o
of installation
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Fluid Drive
rating to shu

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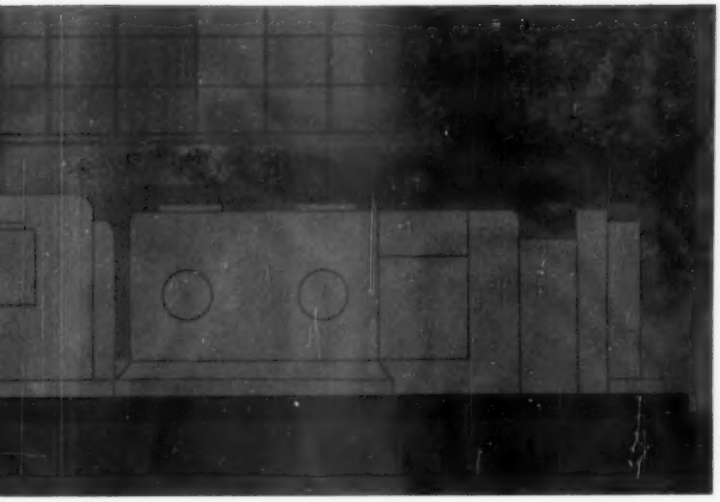
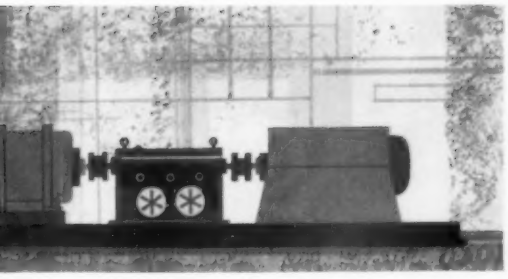
ive offers you a
of field experience and reliability

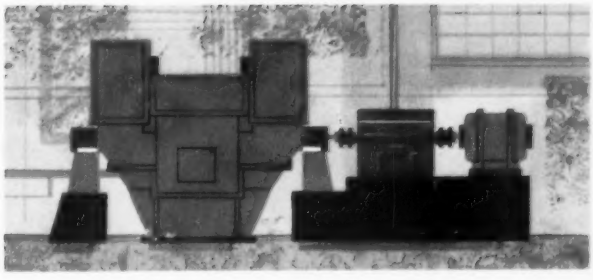


Today more than 4-million horsepower are being driven through Gýrol Fluid Drives in public utilities, industrial power plants, and on industrial machinery of all types. Such widespread acceptance could only come from proved performance in the field.

In power plant applications, not only does Gýrol Fluid Drive's stepless, shockless, adjustable speed pay off in better control, lower maintenance costs and reduced noise levels, but it also provides substantial power savings through lower horsepower requirements.



otor driven boiler feed pumps the ges of Fluid Drive have been proved in hundreds lations over the past 20 years. Through Fluid Drive, le speed savings in pump horsepower are obtained entire actual operating range. In many cases elimif feed water regulating valves and lower initial costs pressure heaters, piping and fittings are effected. rive provides fast, accurate control from full pump o shutoff. Operators like this full-range flexibility.



Fluid Drive on Mechanical Draft Fans. Present day boilers are demanding larger fans requiring higher horsepower and higher speed motors. Problems of high fan WR^2 starting, of fan noise and of fan control are of increasing concern. Fluid Drive provides a better means of driving and controlling today's mechanical draft fans. Fluid Drive can divorce fan from motor for starting. Through adjustable speed Fluid Drive can lower fan noise, reduce fan wear, and save fan horsepower.

, AMERICAN RADIATOR & STANDARD SANITARY CORPORATION

As Near as Your Phone

American-Standard Industrial Division Power-Lift Products and Services

Talk over your requirements with an American-Standard* Industrial Division product specialist. You'll find him well prepared and experienced—frequently able to base equipment recommendations upon precedents of proved success. And, in many instances, our comprehensive standardization paves the way to savings in time and cost. Offices in all principal cities. AMERICAN-STANDARD INDUSTRIAL DIVISION, DETROIT 32, MICHIGAN. IN CANADA: AMERICAN-STANDARD PRODUCTS (CANADA) LIMITED, TORONTO, ONTARIO. EXPORT DIVISION, AMERICAN-STANDARD, NEW YORK CITY.

SURFACE CONDENSERS

Designed to service the largest of today's and tomorrow's steam turbines. Low bundle entrance velocity; liberal steam transportation lanes; moisture impingement grids to extend tube life; expansion diaphragms; effective de-aeration and many other features created during 40 years of surface condenser development and research.

MECHANICAL DRAFT FANS

Complete range of sizes and types for forced draft, induced draft, gas recirculating, and primary air fan applications. Designed to meet rigid requirements of modern power plants where maximum pounds of steam are produced daily at peak efficiency. Airfoil, forward curved, backwardly inclined, radial, radial tip blades.

FEEDWATER HEATERS

Design incorporates unique new High Pressure closure. Maintenance is simplified with only four major parts. Exceptionally high safety factor built into all units—more than double ASME Code requirements. Temperature stresses from start-ups or load changes virtually non-existent.

HEAT EXCHANGERS

Designed and built with thoroughness and precision. Standard or specially engineered units for virtually all conditions and applications, including high pressure-high temperature exchangers, compressor inter- and after-coolers, fuel oil heaters, blow-down exchangers, and many others.

GYROL® FLUID DRIVE

Provides stepless adjustable speed control for fans and boiler feed pumps. Performance, power savings, and reliability proved in the field. Units for motor driven boiler feed pumps or for "on-the-shaft" duty on main turbine generator. Drives are available for fan and pump duties for all boiler sizes.

DUST AND FLY ASH COLLECTORS

Type "D" Dust Collector: mechanical "cyclone-type" collector. Series 342 Dust Collector: uses "cyclone" principle, with individual tubes which permit flexibility in design to fit plant layout. Series 361 Dust Collector: combines primary and secondary systems for high efficiency fly ash recovery.

* American-Standard and Standard® are trademarks of American Radiator & Standard Sanitary Corporation.

AMERICAN-Standard
INDUSTRIAL DIVISION

AMERICAN BLOWER PRODUCTS • ROSS PRODUCTS • KEWANEE PRODUCTS

Babcock & Wilcox nuclear powerplant in the N.S. Savannah. Ionic impurities in the primary loop are removed by AMBERLITE *ion exchange resins.*

AMBERLITE ion exchange resins serve N.S. Savannah's nuclear powerplant

Three years of normal cruising without refueling. This is the astonishing performance that the N.S. Savannah's nuclear propulsion system should make possible.

In this atomic powerplant, which was designed and built by The Babcock & Wilcox Company, a portion of the water circulating in the primary loop will be continuously side-tracked and passed through a bed of AMBERLITE ion exchange resins for ion removal. The deionization is necessary for two reasons: (1) metallic ions exposed to radiation can become quite hazardous, and (2) water impurities could foul the heat transfer surfaces in the reactor core. This purification step will be accomplished by depressurizing about 10,000 lb/hr of water from 1750 psi to 60 psi (also cooling it from approximately 500°F to 110°F) and passing it through a mixed-bed ion-exchange unit containing an AMBERLITE XE-150 type resin. It is anticipated that the quality of the purified water will be in the range of 0.5 micromhos per cm.

AMBERLITE XE-150 is a mixture of specially prepared grades of (1) AMBERLITE IR-120, for removing cations, and (2) AMBERLITE IRA-400, for anion removal. These resins are produced to meet the rigid specifications required by the nuclear field. They are only two members of the broad line of ion exchange resins offered by Rohm & Haas for applications such as softening or deionizing boiler water, recovery of metal ions, processing of pharmaceuticals, catalysis, sugar refining, and analytical chemistry. Detailed technical literature on these resins is available. Also, write for our 24-page booklet *If You Use Water.*

AMBERLITE *is a trademark, Reg. U. S. Pat. Off. and in principal foreign countries.*

Chemicals for Industry

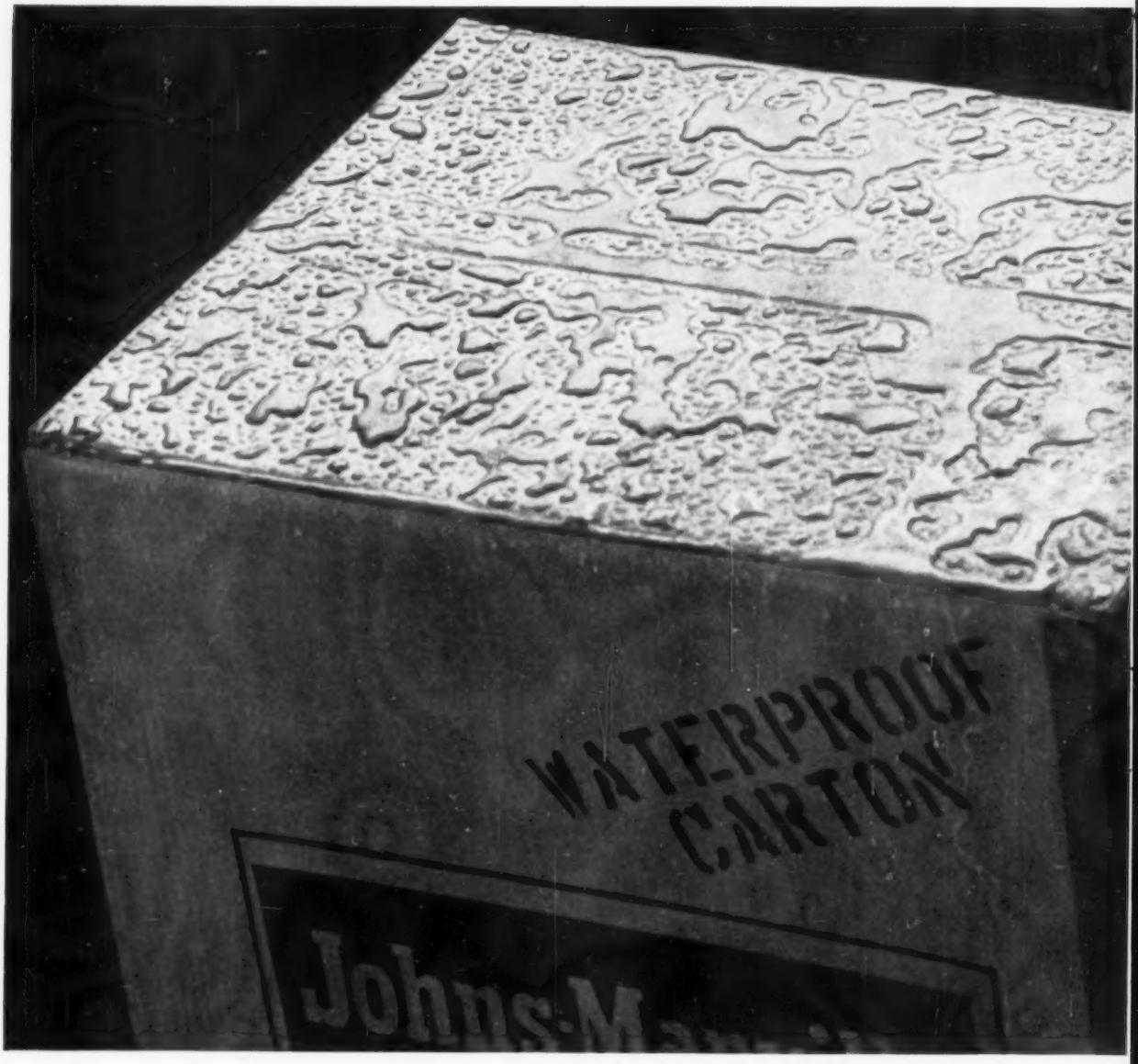
ROHM & HAAS COMPANY

THE RESINOUS PRODUCTS DIVISION

Washington Square, Philadelphia 5, Pa.

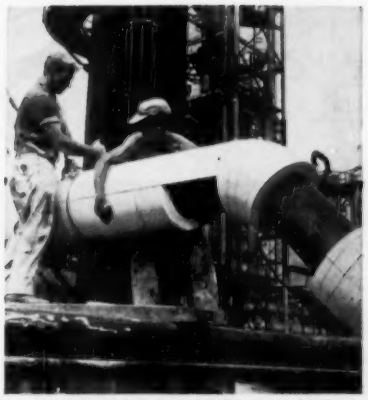
ANOTHER FIRST FROM JOHNS-MANVILLE

Industrial insulations in weatherproof cartons!



All these dollar-saving advantages for pennies more!

- **NO SHEDS TO BUILD**
- **NO HEAVY TARPAULINS TO HANDLE**
- **WEATHERPROOF FOR A MINIMUM OF 3 MONTHS**
- **SAVE TIME, WORK, MONEY ON THE JOB**

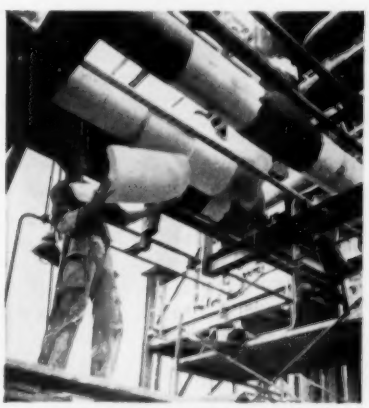


J-M THERMOBESTOS® Pipe and Block Insulation for temperatures to 1200 F., light in weight, top mechanical strength, low *k* factor.

Now, thanks to a new and exclusive Johns-Manville carton, you can do away with on-the-job-site storage problems. Never mind the snow and rain. Just put the cartons on runners or skids—*and forget about weather problems.*

These cartons are proved by actual test to withstand rain and snow up to three full months! No need for sheds, lean-tos, tarpaulins or other protection. For only a slight premium, you save time—work—money. And only Johns-Manville offers you this plus value. Ask your J-M Insulation Contract Unit or your nearest J-M sales office.

J-M SUPEREX® Block Insulation is furnished in flat or curved blocks, and is recommended for equipment operating at temperatures up to 1900 F.



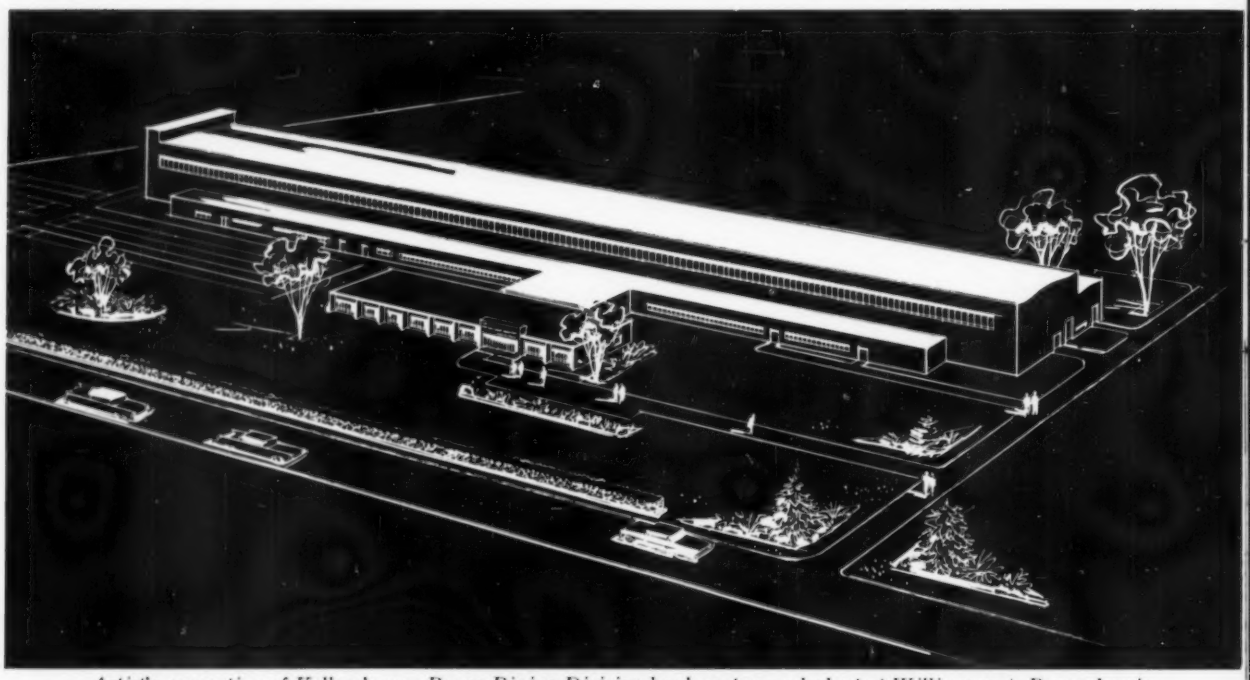
J-M 85% MAGNESIA Pipe and Block Insulation is designed for use up to 600 F. on heated piping and equipment. The standard for decades.

JOHNS-MANVILLE

JOHNS-MANVILLE JM PRODUCTS

AN INSULATION FOR EVERY COMMERCIAL AND INDUSTRIAL USE

To Serve Electric



Artist's conception of Kellogg's new Power Piping Division headquarters and plant at Williamsport, Pennsylvania. The entire site covers about 50 acres.

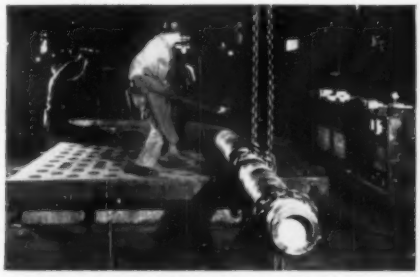
KELLOGG

As operating temperatures and pressures increase in central power generating stations, the need for stronger and superior materials, and for better methods of manufacturing power piping systems, becomes more acute.

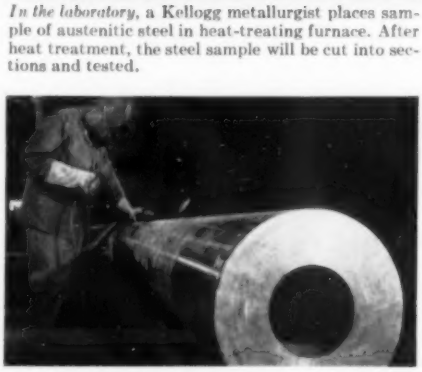
To help solve these problems, The M. W. Kellogg Company's Power Piping Division is building new metallurgical and welding laboratories as part of its complete manufacturing facilities at Williamsport.

The laboratory facilities and personnel, in addition to performing applied research and development for manufacturing power piping, will be available for consultation with clients on their problems and will act as a customer service laboratory.

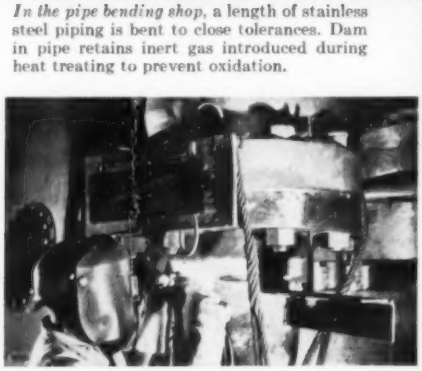
In the laboratory, a Kellogg metallurgist places sample of austenitic steel in heat-treating furnace. After heat treatment, the steel sample will be cut into sections and tested.



In the pipe bending shop, a length of stainless steel piping is bent to close tolerances. Dam in pipe retains inert gas introduced during heat treating to prevent oxidation.



In the welding shop, two heavy-walled sections of stainless steel power piping are joined by K-Weld—an inert gas-shielded technique of arc welding, patented by Kellogg, which assures long life.



In the customer's plant, a Kellogg operator uses K-Weld to install heavy sections of power piping which carry superheated steam from boilers to generators.

Utilities Still Better

Power Piping Division of M. W. Kellogg is Building New Headquarters and Manufacturing Plant in Pennsylvania

To still further improve the service it has given to electric utilities for over 40 years, the Power Piping Division of The M. W. Kellogg Company is now building new headquarters and a plant at Williamsport, Pennsylvania.

Planned for completion by Labor Day, the plant will specialize in the manufacture of high pressure, high temperature alloy and carbon steel piping for electric generating stations. Centrally located in Pennsylvania, Kellogg's Williamsport plant will be within easy distance from many Eastern industrial centers. From here, it is well situated to serve clients by road, rail, or air.

Representing an investment of approximately $4 million, these new facilities will have no equal in the power piping industry. Incorporating the most modern and time-saving equipment, the facilities have been designed throughout for maximum efficiency and economy.

With completion of its new plant, Kellogg will be better equipped than ever to tackle all orders for power piping promptly, and to carry them through to actual installations in customers' central stations from coast to coast.

At its new plant, Kellogg will have the engineering skills to manufacture complex piping systems; the men and equipment to cut, machine, bend, weld and heat treat piping of varying sizes and wall thicknesses.

Here, Kellogg will have the equipment to make electronic, radiographic, ultrasonic and other advanced tests to inspect the quality of the finished product. Here, it will have the metallurgical and welding laboratories to evaluate new and superior piping materials; to maintain a continuing program of development in welding and other manufacturing techniques, and add still further to its line of industry "firsts" listed at the right.

Kellogg's Power Piping Division welcomes inquiries on its new facilities from engineers of power generating companies, consulting engineers, and manufacturers of turbines, boilers, and allied equipment.

OTHER KELLOGG FIRSTS IN POWER PIPING

In 1931, Kellogg manufactured the first all-welded piping for the first high-temperature, high-pressure central station in the United States. Kellogg manufactured the first austenitic steel piping for a central station installation and has been continually experimenting since to establish the best materials, manufacturing techniques and heating cycles for welding and post-welding treatment, and to set specifications for electrodes.

FIRST IN MANUFACTURING OF:

Piping from C ½% Mo
Station piping for 900 F.
Station piping for 950 F.
Station piping for 2200 psi
C ½% Mo piping with
#3-#5 actual grain size
1¼% Cr-½% Mo steam piping
Steam piping for 1000 F.
½% Cr-½% Mo station piping
2% Cr-½% Mo station piping
Station piping for 1000 F.
2¼% Cr-1% Mo station piping
1¼% Cr-½% Mo station piping
1% Cr-1% Mo V turbine piping
2¼% Cr-1% Mo V station piping
Station piping for 1050 F.
3% Cr-1% Mo station piping
Type 347 stainless turbine piping
Mercury vapor piping for 1000 F.
Station piping for 1003 F. for France
Type 347 stainless station piping
Station piping for 1100 F.
Type 316 stainless station piping
Type 316 stainless station piping for
3500 psi-1050 F., 325 MW
Type 316 stainless station piping for
5600 psi-1200 F., 325 MW

KELLOGG

POWER PIPING DIVISION · THE M. W. KELLOGG COMPANY

711 THIRD AVENUE, NEW YORK 17, N. Y. • A SUBSIDIARY OF PULLMAN INCORPORATED

Offices of Kellogg subsidiary companies are in Toronto, London, Paris, Rio de Janeiro, Caracas, Buenos Aires.

Picks coal

International Paper now burns coal as low-cost fuel

When the International Paper Company—one of the largest paper companies in the country—made plans to double its production output, at its Mobile, Alabama plant, an engineering survey was made of power and steam facilities. This study indicated the need for increased boiler capacity. It was decided to install new modern coal-burning equipment.

Coal was chosen when estimates pointed up its low cost compared to other available fuels. And, for full use of coal's inherent energy content, the new power plant utilizes the latest in coal-handling and combustion equipment. Burning coal the modern way continues to pay off in steam generating efficiency and substantial fuel savings for International Paper.

Coal is lowest cost fuel

Today, *when the annual cost of fuel often equals the original cost of the boilers,* you should know that bituminous coal is the lowest cost fuel in most industrial areas. And modern coal-burning equipment gives you 15% to 50% more steam per dollar, while automatic operation trims labor costs and eliminates smoke problems. What's more, tremendous coal reserves and mechanized mining procedures assure you a constantly plentiful supply of coal at stable prices.

Consult an engineering firm

If you are remodeling or building new heating or power facilities, it will pay you to consult a qualified engineering firm. Such concerns—familiar with the latest in fuel costs and equipment—can effect great savings for you with the efficiency and economy of coal.

Technical advisory service

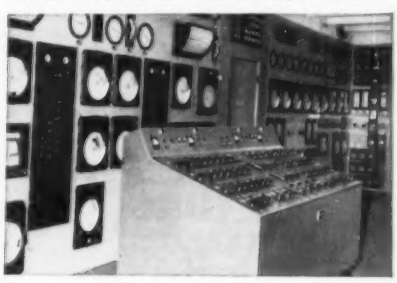
To help you with fuel problems, the Bituminous Coal Institute offers a free technical advisory service. We welcome the opportunity to work with you, your consulting engineers and architects. If you are concerned with steam costs, write to address below or send coupon. Ask also for case histories booklet, complete with data sheets. You'll find them informative.

BITUMINOUS COAL INSTITUTE

Department C-04, Southern Building, Washington 5, D. C.

See our listing in Sweet's Files: A-30J/Bi; PE-4a/Bi; IC-18b/Bi

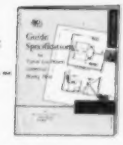
Hagan Boiler and Fuel Control panel regulates two 450,000 lb/hr Babcock & Wilcox boilers for complete, automatic control of steam generation. Generators and steam distribution are also controlled here. Feedwater control, Bailey Meter Co.



for economy!

View from roof of power plant showing river barge delivering coal. Harnischfeger Crane unloads barges into hopper which feeds crusher. From here, Jeffrey Conveyor on right moves coal into inside bunkers, then into 650-ton Neff & Fry silo.

SEND COUPON FOR NEW BCI PUBLICATIONS
Guide Specifications, with complete equipment criteria and boiler room plans:



Bituminous Coal Institute, Southern Building, Washington 5, D. C.
Gentlemen: Please send me:

- ☐ GS-1 (low-pressure heating plant, screw-type underfeed stoker);
- ☐ GS-2 (high-pressure heating and/or process plant, ram-type underfeed stoker);
- ☐ GS-3 (automatic package boiler for heating and process plants);
- ☐ Case histories on larger plants.

C-04

Name_____

Title_____

Company_____

Address_____

City_____ Zone_____ State_____

HIGHLIGHTS

SIGNIFICANT STATISTICS OF C-E REHEAT BOILERS* ORDERED IN '50s

Total number of units—256. Total capacity—36,555,250 kw. Avg. unit capacity—142,790 kw.

NUMBER OF UNITS

	1450 PSI RANGE(1)		2000 PSI RANGE(2)		2400 PSI RANGE(3)		TOTAL UNITS	
5-year periods	Natural Circulation	Controlled Circulation	Natural Circulation	Controlled Circulation	Natural Circulation	Controlled Circulation	Natural Circulation	Controlled Circulation
1950–1954	49	7	25	34	None	3	74	44
1955–1959	23	None	40	39	None	36	63	75
Total	72	7	65	73	0	39	137	119
GRAND TOTAL	79		138		39		256	

CAPACITY—KILOWATTS**

			AVERAGE PER UNIT		LARGEST UNIT	
5-year periods	Natural Circulation	Controlled Circulation	Natural Circulation	Controlled Circulation	Natural Circulation	Controlled Circulation
1950–1954	7,720,750	6,635,250	104,335	150,800	156,250	260,000
1955–1959	6,649,000	15,550,250	105,540	207,335	200,000	500,000
Total	14,369,750	22,185,500	104,890	186,336		
GRAND TOTAL	36,555,250		142,790			

Comments Note that while average capacity of natural circulation boilers is about the same for both 5-year periods (104,335 and 105,540), the average capacity of controlled circulation boilers (150,800 and 207,335) increased nearly 40% in the second period.

Note, too, that while the total capacity of controlled circulation more than doubled in second period, the total capacity of natural circulation boilers decreased.

Of the total capacity of controlled circulation boilers purchased in second period, over 50% was in the 2400 psi range. Average unit capacity in this range was 217,380 kw.

*Exclusive of eighteen foreign units with an aggregate capacity of 2,000,000 kw. Also excludes six C-E Sulzer Monotube Steam Generators, three for supercritical and three for subcritical pressures, with aggregate capacity of 1,300,000 kw. Five Monotube units in operation.

**Turbine manufacturer's rating

Turbine throttle pressures
(1) 1250-1650 psi. (2) 1800-2100 psi. (3) 2350-2600 psi.

of the Biggest Decade in Power History

Progress in power generation moved forward at a spectacular pace in the fifties. Utility capacity increased from 61,700,000 kw at the end of 1949 to 158,800,000 kw at year end, 1959. Thus, in this one decade, capacity soared to a figure nearly two and a half times that achieved in the seven previous decades of the industry's existence . . . Here are some of the significant highlights of power progress in the fifties.

REHEAT CYCLE TAKES OVER . . . GIVES EFFICIENCY A BIG BOOST

Of the new steam capacity ordered in the past ten years, reheat units accounted for about 85% of the total. While other factors, notably higher pressures and temperatures, contributed to improved efficiency and economy, the widespread adoption of the reheat cycle was primarily responsible for reducing the industry's average heat rate from 15,053 Btu in 1949 to 10,900 (est.) in 1959—a gain of nearly 30% . . . Combustion's first postwar reheat units were ordered in 1947 and installed in 1949—one at the Edgar Station of Boston Edison Company and one at the Port Washington Station of Wisconsin Electric Power Company. The impetus these initial installations gave to the adoption of reheat is revealed in the Table opposite.

CONTROLLED CIRCULATION SPARKS THE TREND TO HIGHER PRESSURES

The first postwar C-E Controlled Circulation Boiler was ordered in 1950 by the Virginia Electric & Power Company and installed in the Chesterfield Station in 1952. The many advantages of this design, especially its suitability for high pressures and large unit capacities, were quickly recognized. The result, as indicated by the figures in the Table, was the most rapid and large-scale acceptance ever accorded a new design of utility boiler . . . The Table also discloses the marked trend toward higher pressures with 36 controlled circulation boilers in the 2400-psi class ordered in the past 5 years as against 3 in the preceding 5 years.

OUTDOOR PLANTS GROWING IN POPULARITY

Of 181 new power stations built in the fifties, slightly over half (92) are of outdoor or semi-outdoor construction . . . Many of these stations are in middle and northern states, including such far northern states as Minnesota, North Dakota and Montana. Thus, the economy and practicability of outdoor construction is finding ever-increasing acceptance. Combustion made the initial boiler installations in over 40% of the new outdoor or semi-outdoor stations placed in service in the past decade.

NEW AVENUES TO FUTURE PROGRESS

Supercritical Pressures—In the history of power progress, the fifties will be credited as the pioneering period in supercritical pressures. Through its installations of two C-E Sulzer Monotube Steam Generators at the Eddystone Station of the Philadelphia Electric Company and one at the Avon Station of The Cleveland Electric Illuminating Company, Combustion is acquiring the technical knowledge and experience to keep pace with the adoption of supercritical pressures as the trend develops. Its Eddystone No. 1 installation marks the present pinnacle of progress in pressures and temperatures with steam conditions of 5000 psi and 1200 F.

Nuclear Power—The fifties will also be recognized as marking the first commercial applications of nuclear power. Shippingport, for which C-E designed and built the reactor vessel, led the parade, achieving criticality in December, 1957, followed by Dresden in October, 1959 . . . Nearly a million kilowatts of commercial power is scheduled to go into operation in the early sixties . . . Combustion's subsidiary, General Nuclear Engineering Corporation, was recently awarded an AEC contract to design a boiling water reactor for the Puerto Rico Water Resources Authority to produce nuclear-generated superheated steam. GNEC made feasibility and preliminary design studies for this project and has made other extensive studies in the field of nuclear superheat. This work has special significance since nuclear superheat gives promise of appreciably reducing capital and fuel costs in atomic power plants.

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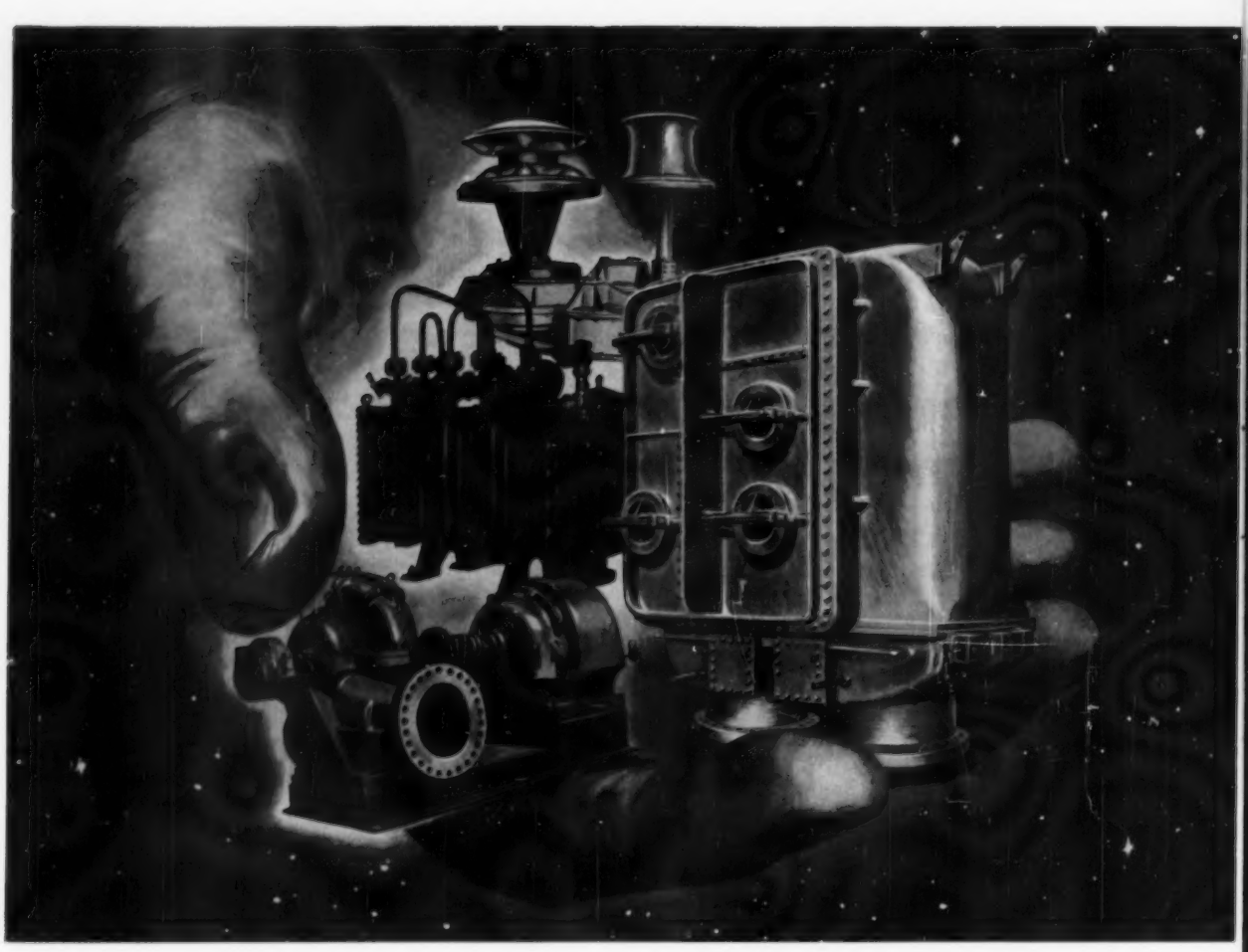

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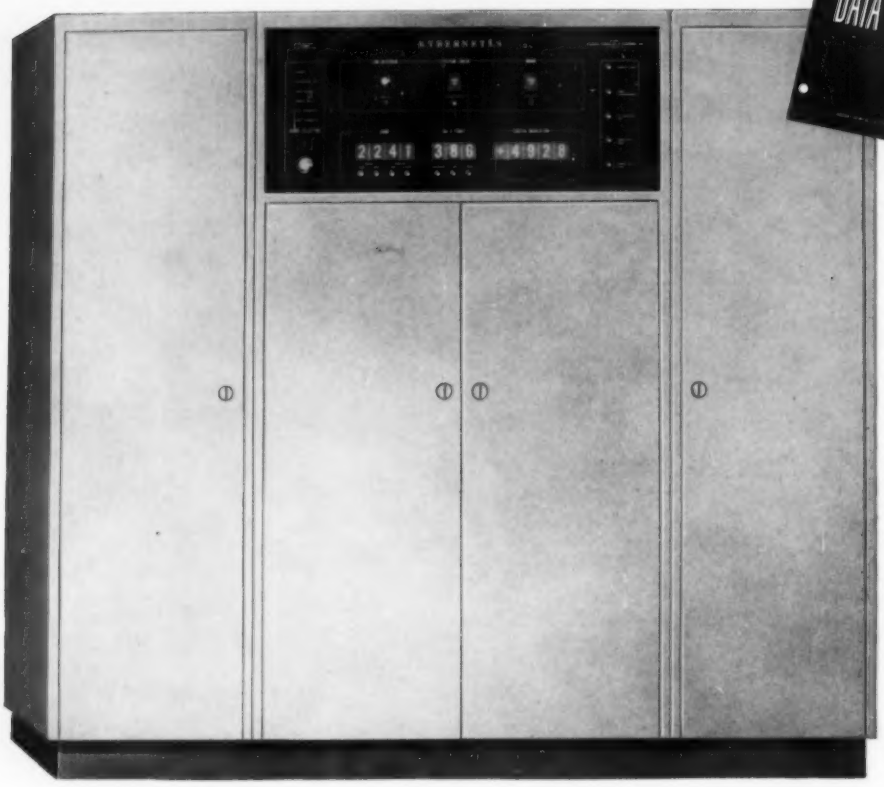

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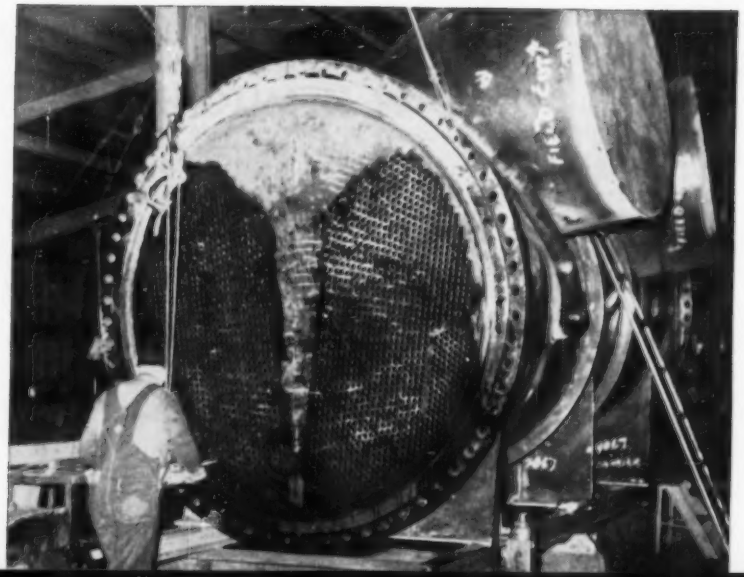

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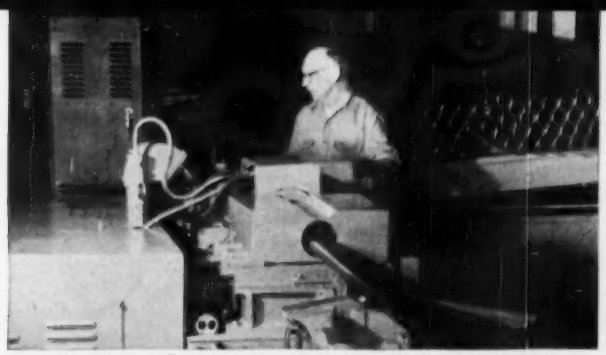

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16	12½% of wall	.003 sq. inches
14 and 13	12½% of wall	.004 sq. inches
12 and heavier	12½% of wall	.005 sq. inches

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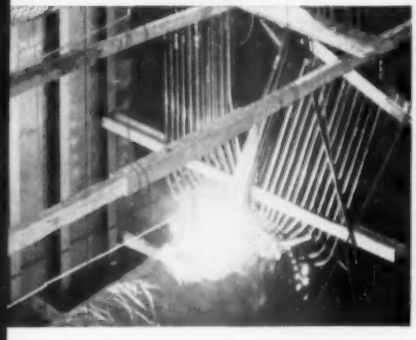
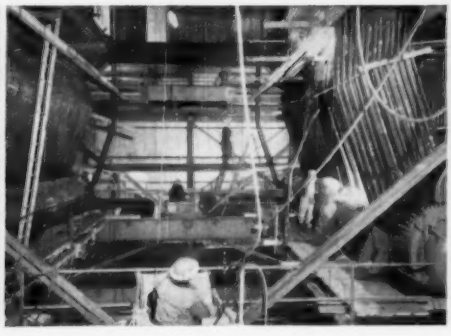


DETROIT EDISON COMPANY Beacon Heating Plant, showing installation of Republic ELECTRUNITE Boiler Tubes in North drums.



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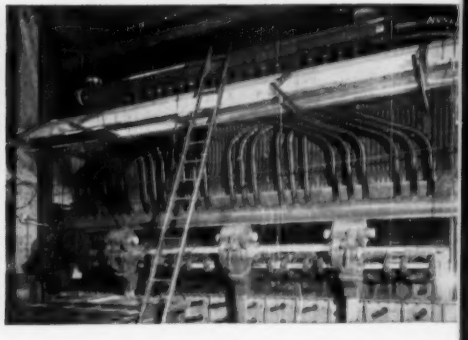

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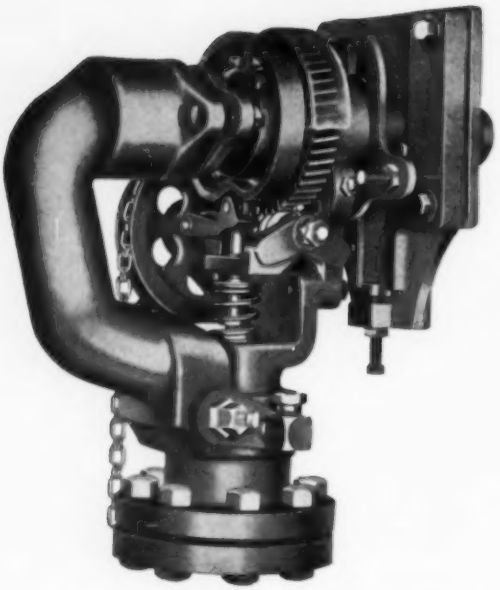

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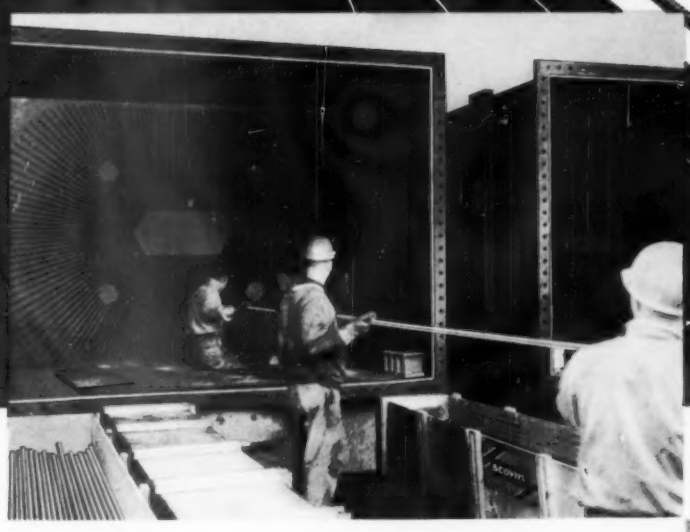

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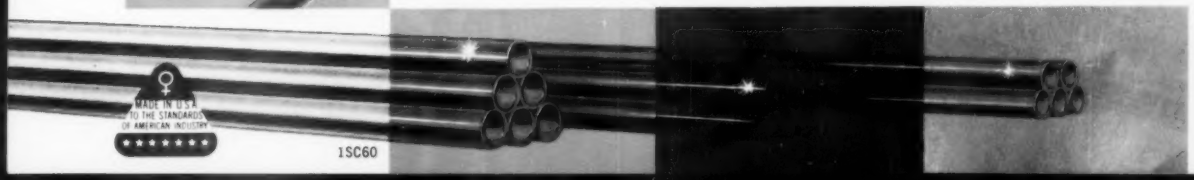

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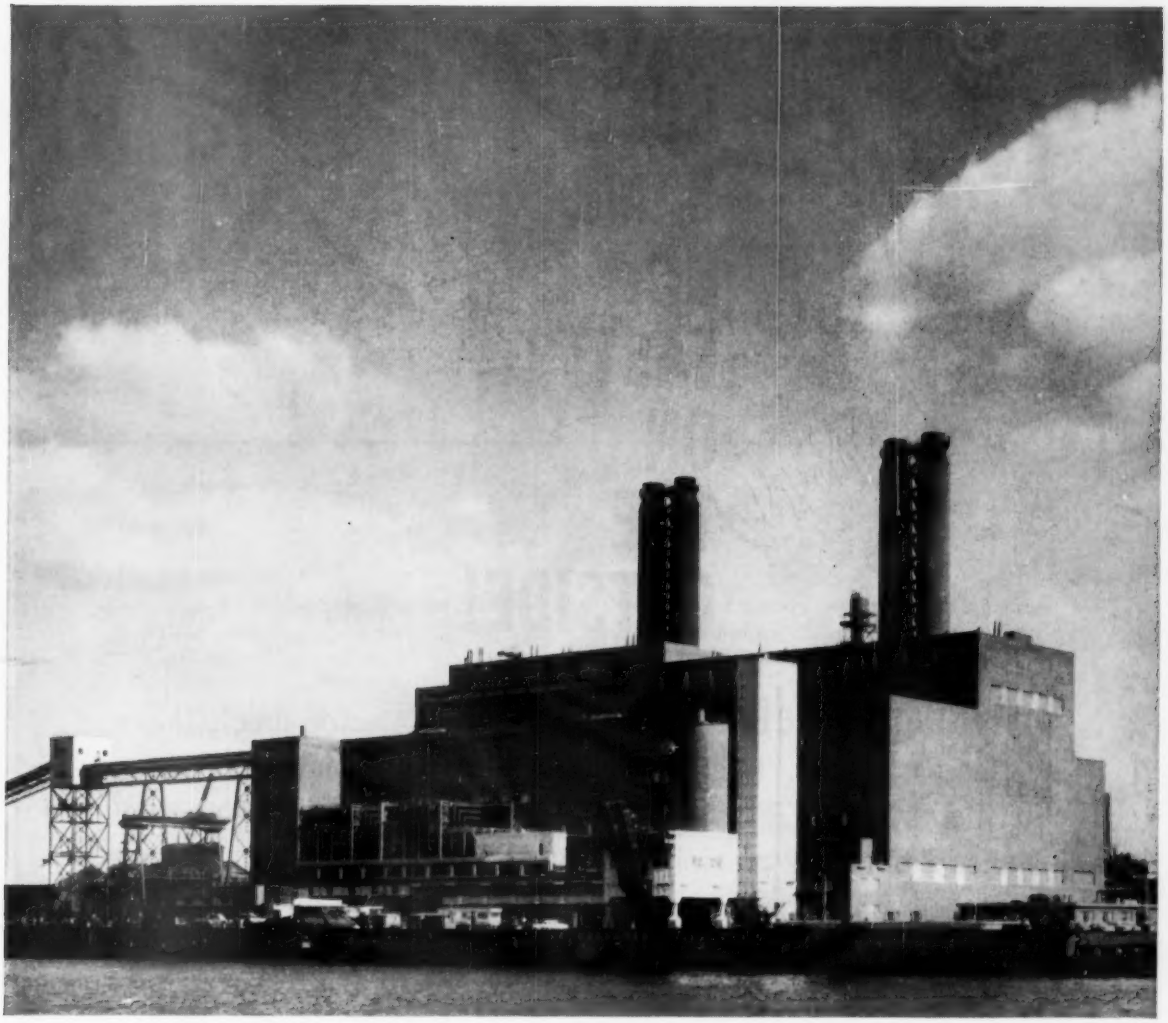

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EDITORIAL

A Modern Heresy

Down through time, as the art of dwelling together is refined we observe that the harshness of punishment is clearly on the wane. Draco is no doubt spinning in his sarcophagus at the meekness with which society turns the other cheek to those who offend against it. Perhaps this is just as well, for the consequences of a return to the practice of whacking off an arm as a punishment for pilfering, for example, would be terrible to contemplate. The application of this code to petty expense account plundering alone could create a staggering national sleeve surplus.

Sober reflection on the general flabbiness of legal mores encourages us to a brief flight into heresy—for which there seems to be no modern punishment. There may not even be such a crime. Heresy may be defined as a departure from Truth and there can be neither Truth nor Justice in a society which suffers the Yankees to trade Hank Bauer without fear of retribution.

To take the plunge without further deliberation—we think some one should change the format of the modern institution known as the Engineering Society Meeting. Clinical studies conducted at the recent American Power Conference by an independent testing company indicate that the average engineer is incapable of retaining more than a few of the barrage of over-decimalized numbers and percentages hurled at him during the course of the average session. Parallel studies indicate that during a single session our average engineer will reflect on his failure to reconfirm airline space, the identity of the gentleman nodding to him from across the aisle, how to arrive simultaneoulsy at three different hospitality suites, etc. He consequently fails to pick up anything except a copy of the paper and a cramped derriere. The former is easily obtainable by mail and the latter in any public conveyance.

We have heard of a group to the North (Canadian Section, World Power Conference) which has met this problem head-on. Registrants for a meeting there receive copies of papers thirty days before the meeting. The author is permitted neither to read nor "present" his paper but is requested to expound and expand on one single aspect of it. This of course frees him from the burden of historical introductions, descriptions of equipment, formulas, analyses and the like. He is encouraged to believe his listeners are familiar with all this through studying his paper. He is thus free to discuss his favorite topic in an intelligent way expressing his technical philosophy as he does so. Speakers may be questioned on any aspect of the paper. It seems to us this approach has much to commend it. At present the chief value of the Meeting as practiced in the U.S.A. is limited to meeting our opposite numbers from all over the land in informal vis-a-vis discussions. The fact that technical papers that might otherwise never see daylight are squeezed from reluctant or busy authors is an undeniable added benefit. Under the system employed at the World Power Conference referred to above we add to these the blessing of lively and interesting formal sessions and we have a genuine contribution to mankind. Incidentally the annoying "commercial" or post-paper prepared discussion which degrades too many meetings would be discouraged in considerable measure.

A recently unearthed letter of Steve Brody's reveals that he was thinking as he hoisted himself over the railing of the Brooklyn Bridge, "What the heck, somebody oughta try it."

Washing Bunker C Fuel Oil—

Problem

The problem of slag and corrosion resulting from the combustion of Bunker C fuel oils has long been with us. The economics of oil supply and consumption are such that this topic has constantly increasing importance. Because of the ever growing interest in this topic we reprint below two articles from the January 1960 issue of *Marine Engineering/Log*. Dr. McMullen's article presents the problem and suggests a method of minimizing its effects. In studying both of these articles the reader should constantly keep in mind the fact that the problem in these marine applications is not the same as the stationary boiler problem.

We are warned that the solution too may differ and we pass that warning along.

Boiler Problems Associated with Use of Bunker C Fuel*

By DR. JOHN J. McMULLEN†

THE STEAMSHIP industry is probably the only one in existence which purchases such an enormous quantity of fuel without any quality control and under such varying conditions. As a matter of fact, most oil companies are reluctant to state the analysis of Bunker C fuel oil. Since the oil is generally purchased under annual contracts, the steamship operator must be prepared to accept bunkers all over the world of widely varying properties. By accepting such variations in the chemical content of the fuel, the steamship operator not only increases his own fuel cost, but also increases his maintenance and repair costs due to the problems created by the use of an uncontrolled by-product Bunker C fuel.

Bunker C specifications define this product only in its broadest sense and are not intended to provide quality control. In fact, no degree of control of the chemical characteristics is possible. Sodium and potassium compounds however, are generally water soluble and can be dissolved by water washing. Vanadium which is undesirable and plays a predominate role in the corrosion problem cannot be simply or economically removed. Sulfur, sodium and vanadium are the most important ash impurities and although other metals are also present such as nickel, iron, aluminum, silicon, calcium, etc.; the concentration of most of these is relatively low.

The formation and accumulation of sludge in the fuel oil system is of paramount importance in any ship Most pre-combustion and combustion difficulties are direct results of this contamination.

Over the years many types of additives, both legitimate and illegitimate, have been recommended and experimented with. We know from our experience certain of these additives are of assistance in solving the sludge problem and in improving the overall combustion of the Bunker C fuel. Unfortunately, many of the products offered to our industry have absolutely no potential to function as an effective additive to the fuel oil.

Once combustion takes place we more often than not encounter boiler fouling, superheater slagging and corrosion in both hot and cold areas of the boiler.

Although much attention in the use of Bunker C fuel has been in connection with its use in gas turbines, similar problems exist in steam and Diesel plants.

(*Please turn to page 46*)

† President of John J. McMullen Associates, New York and the Hudson Engineering Company, Hoboken, N. J.

* Abstracted from a paper presented at the Dec. 8, 1959, meeting of the New York Section of The Society of Naval Architects and Marine Engineers.

An Answer to Slag and Corrosion?

Prescription

The following article offers water washing of Bunker C oil as a solution. It must be clearly understood that the problems of firing residual fuel in marine boilers is different from that encountered with stationary boilers. Therefore we can not assume that the washing procedure which has proved to be an outstandingly successful answer in the marine field is going to be a panacea for land-based boilers. Entirely different problems of economics, boiler design and oil supply have to be considered in thinking about the application of this process to stationary boilers.

But the excellent story from the *S/S Atlantic Seaman* installation reporting continued cleanliness and important savings after nearly a year's trial of the centrifuge system can not be overlooked. We predict that the development of the possibility of land based oil washing systems will be watched with wide interest.

Water Wash of Bunker C Retards Boiler Slag on Atlantic Tanker

By W. A. WALLS† and W. S. PROCTOR‡

ON NOVEMBER 19, 1959, The Atlantic Refining Company was host to a large group of maritime and engineering people interested in observing the fuel-washing system and inspecting the fireside of the boilers on the *S/S Atlantic Seaman*.

As far as is known this vessel has as high a superheater-outlet temperature as any merchant ship, namely, 1020 F. During the past few years slagging in the ship has become increasingly extensive. The recently installed bunker C fuel-washing system represents the first application of this technique for slag reduction on a vessel with oil-fired boilers.

During recent years high-temperature marine boilers, i.e., 850 F and higher, have been plagued by an ever increasing problem of slag formation, especially in the superheater sections. This condition has been promoted by several factors which intensify the problem both individually and collectively.

The very geometry of marine boilers resulting from the compactness dictated by shipboard space limitations is not conducive to efficient removal of tube deposits. Inter-tube spacing is small permitting quick slag bridging. This factor also interferes with soot-blower effectiveness. Flow of combustion gases through the superheater sections is not always designed to keep metal surface temperatures as low as they might be. As superheat temperatures are increased in new designs to achieve greater over-all efficiencies, deposition rates also go up.

Coupled with the geometry and severity of modern boiler operation has been a change in the character of the bunker C fuel oil itself during the past few years. Sodium and vanadium salts, the chief contributors to slagging and high-temperature corrosion, tend to be found in somewhat higher concentrations in today's fuels. This stems from the processing of many new crude oils, particularly certain crudes, which may contain higher concentrations of naturally occurring metal containants. These metals are non-volatile and are left in the residual fraction (bunker fuel) after refinery processing. Industry techniques themselves have been modernized toward the recovery of maximum refined products such as gasoline and middle distillates. The result has been a reduction in bunker fuel yield with the trace metals concentrated to a greater extent.

(*Please turn to page 44*)

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Water Wash of Bunker C *(continued)*

Slag removal from the tightly spaced marine boiler is difficult at best. Soot blowers of the retractable type are partially effective but cannot delay serious slag buildup very long. Water washing has been used with some success, but requires cooling the boiler and often leads to other damage. Manual cleaning is a better method for effective tube cleaning. This, of course, entails boiler cooling and reheating with long hours in between for costly manual labor. The cleaning procedure often damages superheater tubes more than slag itself and the lost time adds to ship demurrage. Slagging attacks tube hangers and supports other boiler components, as well as tubes. Overall shipyard labor and material costs for boiler maintenance are greatly increased.

What Causes Slag

It is generally agreed that slagging arises from a complex combination of sodium and vanadium compounds which have relatively low fusion temperatures. In modern boilers, designed for high temperatures and pressures, these compounds may deposit quite rapidly as a semi-molten mass which cannot be removed effectively by soot blowers. This slag condition progresses to the point where bridging occurs between the tubes which eventually lead to plugged air passages through the boiler.

A number of different methods have been used in combating slagging in stationary boilers and gas turbine applications. Generally, the most successful (depending on the fuel application) have been based on additives or water washing or a combination of both. In large-scale stationary boilers where high-temperature corrosion has been a greater problem than slagging, calcium and magnesium additives as oxides, carbonates or sulfates have been used with some success either in oil mixture or charged dry to the fire box. Natural mixtures, such as dolomite, have also been used. In the gas-turbine field, sodium removal via water washing of fuel coupled with magnesium or aluminum salt additives for vanadium control have been quite successful in providing practical turbine life when operating on bunker fuel. Until recently very little has been published on slag control in high-temperature marine boilers. In the Atlantic fleet, specialized chemical additives have been used, with some, but insufficient, success.

After studying the experience and methods used for other applications, and examining the composition of slags from Atlantic boilers, it was felt that a major reduction in the sodium level of the bunker fuel might offset the effect of vanadium content and result in decreased slagging. Being in the form of water-soluble salts, much of the sodium content could be removed by washing.

As a check on the importance of sodium in slagging, a test program was carried out on the *S/S Atlantic Seaman*, using low-sodium fuels. In June of 1958, 50,000 bbl of "low sodium-normal vanadium fuel oil" were prepared for this test. The ship used this low-sodium fuel from June until October 1958, at which time she went into the shipyard for periodic overhaul. The boilers were opened for examination and no significant evidence of slagging was found.

Encouraged by these results the decision was made to continue the test with an additional 50,000 bbl of bunker fuel. Here again, the bunker-fuel properties were permitted to fluctuate within the normal range, including vanadium contents as high as 250 ppm. Sodium content of the fuel was maintained at 10 ppm or less. With these bunkers the vessel continued in operation until March 1959, when the boilers were again opened and found to be free from slag.

In Fig. 1, the underside of the superheater section of one boiler on the *Seaman* is shown in a completely blocked condition of the type encountered every few months during recent years on this ship. Such a condition makes continued operation of the boiler impossible and compels shutting down, even at sea. The condition of the same tubes after over 7 months' operation on low-sodium fuel is dramatically shown in Fig. 2. Here there is no evidence of significant slag buildup and performance of the boiler at the end of the test was still normal.

Steam temperatures were maintained at the design 1020 F during the test period, whereas on normal fuel frequent temperature reductions were required to control rapid slag buildup.

As a result of these tests it was concluded that the presence of sodium compounds in fuel oil is the principal cause of the slagging problem in high severity marine boilers. Based on this belief, a shipboard fuel-oil purification system was decided upon.

1. Full utilization of the most economic bunkering

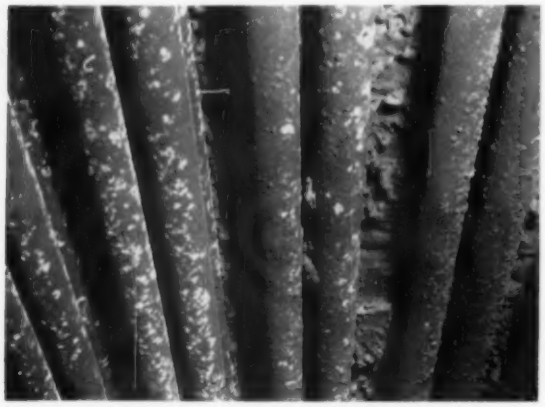


Fig. 1—Superheater section completely blocked and hidden by slag behind screen tubes. This buildup took just a few months

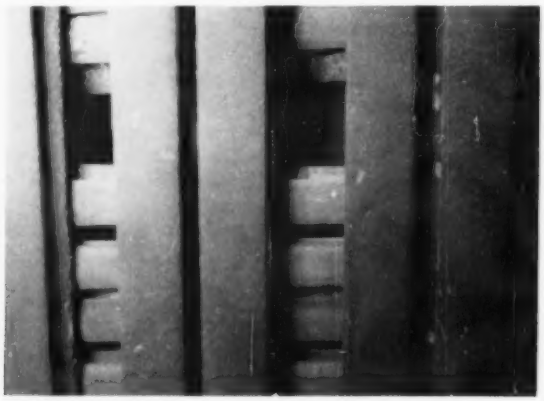


Fig. 2—Same boiler after 7 months operation on water-washed Bunker C. Washing removes 75 per cent of sodium compounds in the fuel

points, which previously had not been recently possible due to the poor fuels available at some ports of call.

2. Substantial reduction in shipyard and overtime labor and repair costs.

3. Decreased ship demurrage.

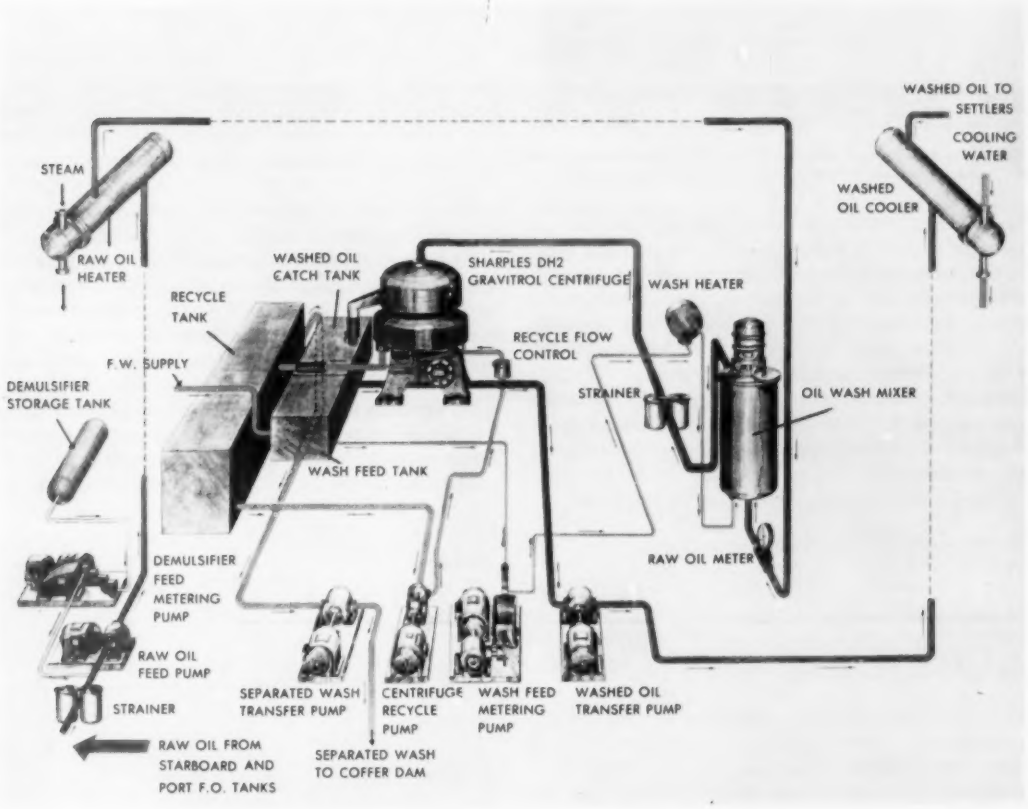
4. Discontinuance of "anti-slagging" additives. With these savings the water-wash investment is expected to be paid off in roughly 2 years.

In this system the fuel oil is mixed with approximately 5 per cent of water and an emulsion-breaking chemical and then run through a centrifuge. The water dissolves the undesirable sodium compounds, which are removed from the fuel, along with the water, by the centrifuge. In this manner it is hoped to remove between 75 and 80 per cent of the sodium compounds present in the bunker fuel

The unit was installed and put into operation on the *Seaman* in August 1959. Since that time there has been no significant indication of slag buildup in the boilers as was evident from the inspection tour of Nov. 19, 1959. The experiment cannot as yet be considered conclusive and much remains to be learned about this problem

Atlantic plans to continue the test through May 1960. At that time the *Seaman* will be put in the shipyard for regular overhaul. Boilers will be completely inspected for evidence of tube deposit. Tube diameters will then be checked to determine if vanadium corrosion has become more pronounced.

At that time Atlantic plans to present a more complete report of their endeavors in this field with a paper delivered at the October 1960 meeting of the Philadelphia Section of The Society of Naval Architects and Marine Engineers.



The Sharples system installed in the S/S ATLANTIC SEAMAN provides a simple and efficient method of washing residual fuel oil. This washing action is accomplished by the introduction of 5 per cent of water to the oil to be processed. In this way water-soluble contaminates in the fuel can be dissolved and removed by centrifuging.

The system incorporates a single centrifuge (Sharples Gravitrol Model DH-2 which removes about 75 per cent of the sodium content of the oil. (Sodium is the prime contributor in formation of slag deposits which impair the efficiency of a boiler.)

In the Sharples system, Bunker C is taken in (at the lower left of the flow diagram above) through strainers and a raw-oil feed pump. At this point a very small quantity ($1\frac{1}{2}$ gallons per 6000 bbl) of emulsion-breaking Tretolite is added through a metering pump. The raw oil then passes through a continuous raw-oil heater which brings it close to 200 F to the oil-wash mixer. The heater is of baffled construction.

Here, 5 per cent of hot water is added and thoroughly mixed with the oil. This mixture then passes through protective strainers to the centrifuge. This is a centrifuge of high efficiency which permits satisfactory separation when using only untreated water for washing.

The washed oil goes to a catch tank whence it is transferred by pump through a cooler to the boilers or intermediate storage. The water-sludge discharge through the nozzles of the centrifuge enters a recycle tank. Thence it is pumped by recycle pump back into the bottom of the centrifuge bowl to satisfy the discharge demands of the 12 nozzles in the Gravitrol bowl.

The separated water goes to the cofferdam. The system is continuous and automatic with floats and controls to maintain it in operation and in balance through the duration of voyage.

Fig. 1—Effects of corrosion and slag buildup in superheater section of a marine boiler. Contaminants in Bunker C fuel are prime problem

While there is considerable controversy as to the mechanism of deposit formations, the low melting temperatures of sodium and vanadium compounds seem to play an important role in the initiation and subsequent buildup of slag formations. Sodium sulfate usually constitutes a large percentage of these deposits with the balance being oxides, vanadates and sulfates of other metals present. Melting points of some of the possible slag components are therefore interesting in suggesting a basis of selective deposition and of the physical state of observed deposits which range from lightly sintered ash to hard fused formations bonded to metal surfaces.

Melting Points of Possible Deposit Compounds

Compound	Melting Point, deg. F
Sodium pyrosulfate ($Na_2S_2O_7$)	1260
Vanadium pentoxide (V_2O_5)	1275
Sodium sulfate (Na_2SO_4)	1625
Sodium metavanadate ($NaVO_3$)	1165
Sodium pyrovanadate ($Na_4V_2O_7$)	1170–1210
Sodium orthovanadate (Na_3VO_4)	1560–1590

It will be noted that sodium metavanadate and sodium pyrovanadate have lower melting points than vanadium pentoxide. Furthermore it has been reported that eutectic mixtures of V_2O_5 and sodium metavanadate and sodium pyrovanadate and sodium metavanadate have melting points of 1050 F and 1070 F, respectively. Sodium sulfate also forms an eutectic mixture with V_2O_5 which has an even lower melting point—below 1000 F. The presence of sodium in the oil is thus shown to be highly undesirable in that sodium compounds of quite low melting points are possible.

As a result of extensive operating experience in the Gas Turbine Ship *John Sergeant*, it has been thoroughly proved that the characteristics of the Bunker C fuel which is most required is "washability," i.e., that it can be desalted by washing. After washing for sodium removal it was possible to inhibit the vanadium. For this purpose, since the gas turbine operating temperature was 1450 F, a water-soluble magnesium sulfate additive was mixed with the washed oil for prevention of turbine deposits and corrosion at a weight ratio of 3:1 Mg/V. Of course, if the vanadium content is low, the amount of additive required is correspondingly less. Nevertheless, the principal point is the removal of sodium to minimize deposits inasmuch as sodium promotes extremely rapid deposit formation appearing predominantly as Na_2SO_4.

During the 3 years' operation of the GTS *John Sergeant* (9270 hr), several different types of fuels were washed. It has been demonstrated that, as long as it was possible to wash the fuel oil in the centrifuges, even high vanadium Bunker C could be burned. Inspection of all the components, including the turbine, compressors and regenerators after three years of operation, clearly indicated that no corrosive non-water-soluble deposits had occurred and that the unit was as sound and as clean as when she operated on distillate fuel. Improved efficiency and lower maintenance more than offsets the fractional cost increase associated with washing of the oil and inhibiting of the vanadium.

In steam boilers, the principal problems associated with the use of Bunker C fuels are: Slagging of the superheaters, vanadium corrosion, oxidative corrosion in the hot zones and sulfur deposits in the airheaters. In addition, there is slagging on the brickwork as a result of ash deposits. Of all these problems, vanadium depositing in the form of V_2O_5 is the most damaging, although the rapid buildup of Na_2SO_4 is also significant.

Vanadium is present in residual fuel oil and in crude oil as oil soluble compounds. During the process of combustion, it may be oxidized to five different oxides, the most important and stable form of which is vanadium pentoxide. This vanadium pentoxide is reddish-yellow in color and while it is seldom observed to have this appearance in slag formations of boilers, there have been reddish deposits observed on Diesel-engine piston heads. These upon analysis revealed an equivalent to 93 per cent vanadium pentoxide.

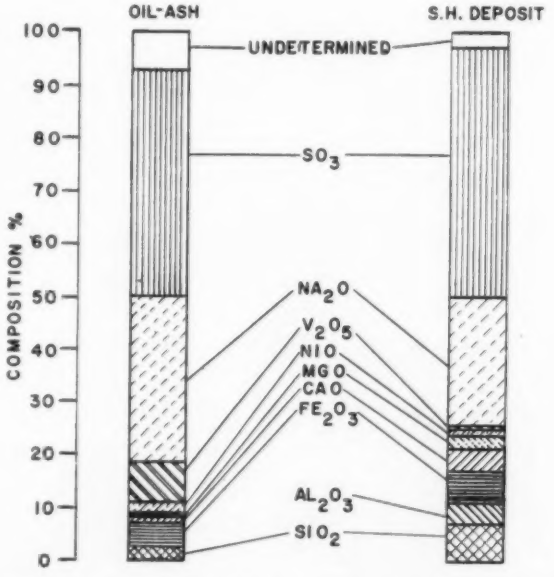


Fig. 2—Typical analysis of oil-ash and superheater deposits from troublesome fuels

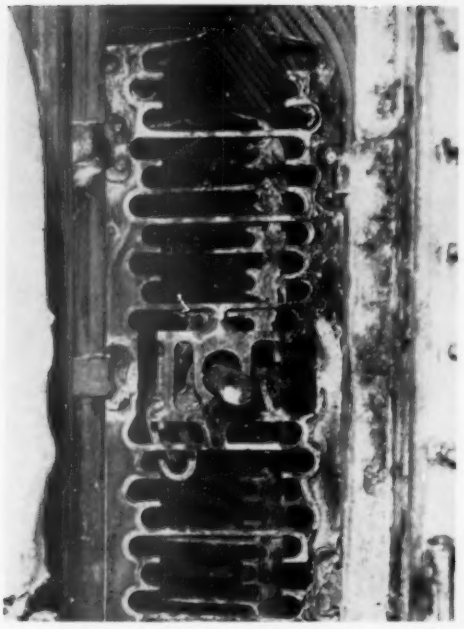


Fig. 3—Superheater supports showing corrosion of support castings

The complex vanadates are the chief sources of concern. It has been reported that the most corrosive vanadium pentoxide-sodium sulfate mixture contains between 10 and 20 per cent sodium sulfate. This corresponds to the formation of sodium vanadyl vanadate, whose melting point of 1157 F is well within the range of, not only gas-turbine operating temperatures, but also steam boiler tube temperatures.

It would be too expensive to remove all of the ash, but nevertheless if the total ash content were less than 400 ppm, the problem would be significantly less because, at least in steam boilers, washing would not be esential.

One steamship operator engaged in the North Atlantic service kept close account of the fuel oil which he received over a period of several years. During 1956, the total ash content of his fuel averaged approximately 825 ppm. During this period, it was necessary to clean boilers every other trip in order to maintain superheat temperatures. As a result, the steamship operator demanded that the oil company deliver oil of less than 400 ppm total ash. Since he was operating a relatively low-temperature steam-turbine plant, vanadium pentoxide was no problem. It was simply necessary to control the sulfur to approximately $2^1/_2$ per cent by weight in addition to the ash control in order to achieve all desired effects. As a result it was possible to cut his boiler cleanings from eight times per year to less than twice a year.

In effect, therefore, the results of uncontrolled Bunker C fuel oil are higher maintenance costs and loss of efficiency. In order that the M&R costs be presented in their proper perspective, it is necessary to present an approximation of their overall effect on operating costs. Basically, the total M&R costs represent about 7 to $7^1/_2$ per cent of total operating costs. While this percentage may appear small in the overall, in terms of dollars it has a rather large effect.

Of the total M&R costs, about 26 per cent can be associated with the engine room. Of this 26 per cent, well over half may be assigned to the boiler maintenance itself.

The best solution to the problem of burning Bunker C fuel is in making certain that the fuel is washed.

If (in the marine industry) we could, for instance, begin to compile the following type information at a central source we could, with proper evaluation, possibly contribute more in 2 years than all reported accomplishments in the past 10 or 15:

1. (*a*) When ordering bunkers insist upon the total ash content appearing on the delivery receipt. (*b*) Instruct vessel personnel to take representative bunker samples for future analysis.
2. Prior to cleaning boilers take samples of deposits identified as to temperature zones.
3. Furnish operational data on boiler firing conditions, ballasting procedures and a few other quite simple log abstracts.

It is the writer's opinion that the major marine boiler manufacturers will agree in principle with most conclusions and would be delighted to assist and co-operate to accomplish this goal.

A more immediate solution would be for owners and operators to join together in urging the oil companies to supply a better oil with less than 400 ppm. ash.

Russian-English Translation Aids Offered Engineers

Russian-English editions have been published for international standard recommendations on steam turbines, auxiliary machines on motor vehicles, and electric transmission of vehicles with diesel engines.

IEC Publication 45, Recommendations for Steam Turbines, Part I, Specification, IEC Publication 101, Rules for Auxiliary Machines on Motor Vehicles (Electric Motors and Generators), IEC Publication 102, Rules for the Electric Transmission of Vehicles with Diesel Engines (Main D-C Motors and Generators) are available from the American Standards Association.

The availability of these Russian-English tests on facing pages should be of assistance to the technical writer, engineer, and the technical librarian concerned with translation of such material.

The price per copy is: IEC Publication 45, $3.20, IEC Publication 101, $2.40, and IEC Publication 102, $3.00. They are available from the American Standards Association, Dept. PR 138, 10 East 40th Street, New York 16, N. Y.

Background photo shows Cooper-Bessemer FM compressors for soot blowing service in a large western utility.

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...a report on soot-blowing applications by
L. B. Schueler, *Power Plant Consulting Engineer, The Cooper-Bessemer Corporation*

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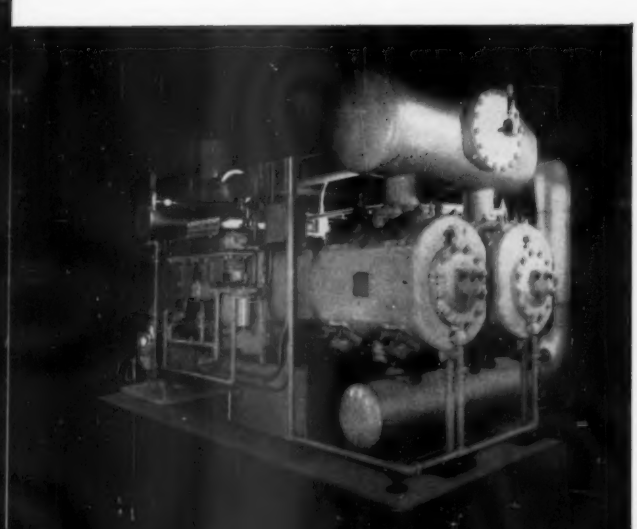

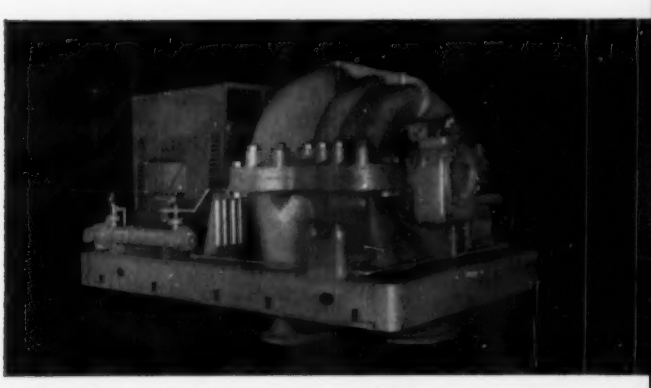

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Feeling the need for free and open discussion of some of the major power problems currently facing industry, *Combustion Engineering Inc.* recently arranged for the first in a series of Industrial Power Forums. This initial Forum was held at Atlantic City during the Annual Meeting of the ASME and was spotlighted by a meeting on the previous day featuring papers on this subject by two authorities who subsequently sat as panel members for our Forum. Last month we presented the first part of our report on the Boiler Safeguards Conference. Here we present the final installment of this Conference.

The Combustion Engineering Industrial Power

In advance of the session all panel members were advised that the objectives were new ideas, untrammeled personal opinions—with the clear understanding that no comment by any individual would be construed as representing his company's policy and that no comment would be associated with an individual's name if he had any objection.

Flame Sensing and Flame Failure

Having considered when to trip a burner or system of burners the group turned rather naturally to the matter of how one determines that a burner or system should be tripped.

A. P. Olches . . . "We believe there are suitable flame sensing devices available on the market. But the problem is more fundamental than the equipment involved. A temporary cessation of air flow or fuel supply will shut a unit down. A better knowledge of safe air to fuel ratios is necessary, or maybe it's a better way of measuring them. O_2 meters as burner safety devices we think have been overlooked and a thorough study of them may prove worth while."

Editor's Note: Another comment by Mr. Olches (actually made later in response to a statement on pilots) is presented here since it bears directly on this subject.

A. P. Olches. . . . "Loss of flame is, to us, not the difficult situation. A temporary air interruption represents the more dangerous condition."

C. E. Savage. . . . "Normally flame failure systems operate with an auxiliary minimum air

THE SCHEDULED PANEL	UNSCHEDULED PARTICIPANTS
M. L. Crull, Department of Water and Power, City of Los Angeles, California	**H. H. Bickel,** Wickes Boiler Company
A. B. Dunn, Department of Water and Power, City of Los Angeles, California	**P. C. Euchner,** Combustion Engineering Inc.
M. L. Jones, Principal Power Engineer, E. I. Du Pont de Nemours & Company	**W. S. Tallon,** Electronics Corp. of America
R. Longstreet, Minneapolis-Honeywell Regulator Company	**John Hochuli,** Gibbs & Hill, Inc.
J. G. A. Mitchell, General Sales Manager, Panel Systems, Combustion Control Div., E. C. A.	**W. F. Lange,** Peabody Engineering Corp.
A. P. Olches, Chief Engineer, Peabody Engineering Corp.	**E. G. Peterson,** Peabody Engineering Corp.
C. E. Savage, Engineering and Construction Div., American Cyanamid Company	**K. Blaine,** Electronics Corp. of America
J. B. Smith, Chief Engineer, Factory Mutual Engineering Division	**A. L. Thompson,** McGill University
L. C. Walter, Republic Flow Meters Company	**J. E. Volpe,** Peabody Engineering Corp.
A. W. Hindenlang, Combustion Engineering Inc.	

Forum—Conference I; Boiler Safeguards

C. E. Savage *(continued)* flow switch or some other shutoff device to combat this condition."

A. P. Olches "We don't believe they can build this protection element sensitive enough to measure as small a variation as may occur in a moment's interruption and react fast enough to guard against it."

A. W. Hindenlang "What is the experience with combustion control equipment currently on the market? Those that measure fuel flow and air flow balance the flows and use this balance to control. Could not a significant imbalance trigger an alarm indicating off-ratio firing. Has this been done?"

Louis C. Walter "It's the old problem of not having any device quick enough to react in time."

M. L. Jones "We're getting back to a basic. Shouldn't there be an operator on the spot? We believe in giving him the tools. In fact, we've oxygen measurement as a vernier to trim the fuel feed. We have not yet used a combustion analyzer, however, on the final fuel tripping device because we're still a little leery of their response."

Louis C. Walter "We must agree. There is a definite time delay between the sample and the analyzer's reaction to it." This time delay may or may not be significant in the action of these devices depending on the particular circumstances.

Louis C. Walter

In discussing gas analyses I am afraid I did not make myself clear when I said "a device quick enough to react in time," while I meant "any gas analyzing device which would be quick enough to react in time." As you know it takes some time for the analyzer to draw the gas sample from the boiler and also takes some time to analyze this sample. I am wondering whether an explosion could occur before the present day analyzers would have indicated that an imbalance existed between fuel and air.

Another problem here is determining the correct point at which a sample should be taken, which would be representative of a dangerous condition. Fuel-flow and air-flow of course could be used, but these measurements can be very inaccurate below a 4-to-1 or 5-to-1 range, and might not be of any value under low fire conditions. Furthermore as I believe I mentioned at the meeting in order to measure air very accurately it might require a lot of money and space used for duct work to properly locate a differential medium.

A. P. Olches

"When you consider you want a trip-out time of one second or less . . ."

Arthur Dunn

"The trend today is to use the combustibles analyzer as a trimmer and an alarm to keep you out of trouble; however, we feel it will be connected directly into boiler controls in the near future."

J. B. Smith

"To rule out the idea of using oxygen combustibles as a flame-out device is too general a statement. How about a 16-burner job where you may lose only one burner? You would not want to shut the whole works down. And the combustion analyzer would not do this. Single burner jobs are different and require different devices."

A. W. Hindenlan

"No burner was ever built to fail. The troubles are not with the burners themselves but with the supplies to the burner. If all the sources of supply to a burner, fuel flow and pressure, air flow, fuel temperature, Btu content of fuel, quality, flow and pressure of atomizing agent are insured a burner cannot fail except in the way of the air to fuel ratio. A combustibles analyzer serves well for this purpose."

Editor's Note: We see illustrated in this phase of the discussion the great paradox of the "flame safeguard" controversy. Aside from Mr. Olches' initial comment about suitable flame sensing devices being available no one even mentioned a flame safeguard unit. In fact it was brought out that a properly supplied burner cannot fail. This trend in the discussion to our mind represents real progress—where for years past the flame failure device itself has been overemphasized there now appears to be considerable thought devoted to placing it in proper perspective and getting on with the very important job of engineering safety into the overall burner system. From the sentiments expressed we are evidently going to see oxygen and combustibles analyzers playing a larger role in consideration of protective systems. Incidentally although it was not mentioned above the combustibles analyzer appears to be the only reliable means of determining the necessity for purging a furnace prior to light-off.

PANELISTS REBUTTAL

Arthur Dunn

I believe there is a definite misinterpretation of the comments in this paragraph under *Editor's Note.*

Your transcript implies *overemphasis* of the importance of the flame detector by the industry. I must disagree on this point. It is my belief the greatest error has not been with overemphasis of the importance of the flame detector, but with the *absence* of a reliable flame detector around which most automatic boiler safety controls have been designed. Mr. Smith, of Factory Mutual, has several times, in his paper on boiler explosion as well as at this forum, stressed the importance of having two instruments for maximum safe coverage of boiler operation; i.e., (1) flame safeguard, and (2) combustibles analyzer. This I agree with completely.

The industry has recognized the importance of the flame detector by connecting it directly into boiler controls and has used the best equip-

ment available for the purpose. The fact that a strong standardization code is being asked for now by the industry is indication that weaknesses and limitations do exist in the present boiler control schemes now being offered by the manufacturers. Certainly one weak link has been the flame detector. Evidence of this statement can be found elsewhere in your transcript where some manufacturers now insist on specifying the size and types of installations as well as conditions under which their flame detectors are installed. It is my observation there has not been a flame detector on the market until the past year suitable for monitoring boiler controls without compromising conditions. Without a regulatory code, marginal and unsatisfactory installations were bound to occur, resulting in loss of confidence in overall safety schemes. Your mention of designing safety into the overall burner system is admirable; but how do you propose to accomplish it? According to statistics, the absence of flame in the burner is the starting point of a large majority of firing difficulties, and it appears this is the one area that obviously must be monitored with 100 per cent accuracy. Is there a better way of monitoring a flame than with a flame detector?

Just as a point of information, I would like to mention our experience with the flame detector which shows such promise and is referred to in the previous paragraph. You are no doubt aware of the introduction of the flame detector within the past year which is sensitive only to the ultra-violet section of the light spectrum. Our organization has had this instrument under test for six months on an alarm basis with such good results that we recently connected it into the safety controls of a large multiburner boiler where it has operated satisfactorily several times as a start-up and shutdown instrument. Results from this installation have been most gratifying and indicate this instrument will place the flame sensing device back in the proper perspective of safety controls.

Lou Walter

In regard to your summation, I did not come away with the feeling that oxygen and combustion analyzers, in their present development at least, would be of much value for protection against explosions. I was under the impression that some recent experiences show that this method was not altogether foolproof.

I personally feel that before these analyzers can be used extensively they must be made more reliable.

At the present time we do use oxygen recorders as a trimming device in connection with combustion control. However the control systems are always set up so that they can be locked out of the circuit in the event that they get out of adjustment.

Editor's Note: It should be realized that the panel members being intimately familiar with the various flame sensing devices, failed to devote any discussion to their nature and functioning.

PANELISTS' REBUTTAL

Arthur Dunn

Again, Mr. Hindenlang, I must dissent. Your remark that, "panel members being intimately familiar with the various flame sensing devices failed to devote any discussion to their nature and functioning" must be answered. In the first place, most of those present were acquainted with the general state of the art and were fully aware there were suppliers also present who have sold boiler controls to the industry which have given marginal performance. There is no doubt these suppliers would have protested loudly if their product had been criticized and could very well have upset the general tone of the meeting, which was cordial and polite. The tempo of the meeting was quite fast; many points were covered and not much time was allowed for dwelling on points which might have produced the discussion which you state was missing. At your next meeting, however, I suggest you brace yourself and ask the question, "What is wrong with the flame detectors of today, and are they really necessary?"

I predict that you will find a much different answer than you indicated in the transcript and will then agree there is no more important instrument in automatic boiler safety controls than the flame detector!

Approach to Application Safeguards

Editor's Note: The discussion turned here to the application of safeguard equipment in various types of furnaces.

James G. A. Mitchell — "The different fuels require different conditions. Large units mean you must consider burner configurations. There are different conditions on each set-up. Utility boilers have an entirely different set of conditions."

A. W. Hindenlang — "Yes, but shouldn't there be a standard approach?"

James G. A. Mitchell — "With up to 4 burners there is such a standard today. If your power sources are good you can get good air measuring devices and other interlocks that work well. In short the elements have all been fairly well proved out. With more than 4 burners, though, the story is different. The elements fall down. You can't single out which burner has failed. It's like optics. You can't look at one man across this table without seeing his neighbor."

A. W. Hindenlang — "Continuing this application problem further than just scanning, can't you take steps to protect against minimum air flow? For example, have Peabody Engineering people spell out the limits of operation for a set of burner, pilot and scanner equipment and then have Mr. Smith of Factory Mutual say for this given set of conditions we would endorse."

J. B. Smith — "Yes, we could approve such a package for operation within definite limits."

A. P. Olches — "This would cause problems for us. In the early days minimum gas pressure or minimum oil pressure was the basic trip-out control. Today we know this too is inadequate. For units of more than 4 burners, operating at loads above 40 per cent, we would have no hesitation in specifying minimum air flow conditions. It is very low load operation that causes the trouble."

M. L. Jones — "Why should 4 burners prove such a magic number? Anything above one is a problem."

A. P. Olches — "With 4 burners you can angle your controls or your protective devices."

M. L. Jones — "We had a blow-up with just such a scheme, two pair of burners, one above the other."

William F. Lange — "To have an explosion with properly scanned burners you must have had burners that were improperly adjusted."

A. W. Hindenlang — "Burner on, burner out—isn't the right approach to build a burner pilot and safeguard equipment as a package to meet specific conditions?"

William F. Lange — "How can you possibly provide protection for the whole range of conditions you impose upon a boiler?"

A. W. Hindelang — "You could establish a normal operating range suitable for good burner operation beyond which interlocks would call for shutdown. Off-ratio firing at very low rates could be supervised by O_2 and combustibles analyzers as Mr. Smith suggests with an alarm or trip as desired."

Editor's Note: Here the disagreement between panelists is so obvious that it becomes nearly impossible to find any area of agreement saving the fact that no one is satisfied with affairs as they stand today. Mr. Mitchell observes that there is a standard today for four burners or fewer. Reflection indicates that this is true only of the scanning arrangement for certain burner-furnace configurations. Flame safeguard plus some interlocks are offered in "standard" packages but these are seldom duplicated exactly in sufficient number to deserve the "standard" description. Where such standard packages are duplicated the degree of protection may vary widely because of the different natures of the furnace systems. The proper approach to standardized safe application seems to need better definition—one beginning might well be made by establishing operating limits for each burner-ignitor-scanner package.

PANELIST'S REBUTTAL

Arthur Dunn — At this point there is definite disagreement as you have indicated. The point that disturbs me in this part of the discussion is the extent to which the industry will fire boilers with a flame-out condition in one or more of the burners and expect the rest of the boiler to support this malfunction. This condition sets up two-stage combustion which can be very hazardous and certainly should be avoided. The solution to this problem appears straightforward and the hardware to do it is available. The scheme would consist of integrating air register operation into the single burner controls so that when a flame-out condition is indicated by a single burner flame detector, the air register and fuel valves to that burner would close. Your remark, "isn't the right approach to build a burner pilot and safeguard package of equipment to meet a set of specific conditions," indicated you were thinking along these lines. If there is any concern about remote operated (electric drive) air registers, we have used them for five years on large multiburner boilers and have found them satisfactory. We could not fire remotely without them.

Controlling air registers automatically seems the next obvious step in the refinement of industrial boiler controls. Its integration into a unitized burner control system similar to that employed today on some large multiburner boilers could very well be the answer to a great many of the industrial boiler safety control problems.

Purging

As a function that is a vital part of proper start-up procedure, which often enters the area of "on the line" operating procedure and concerning which there has been a tremendous amount of controversy; the furnace purge came in for some attention.

M. L. Jones — "Is this start-up purge a permissive manual function or something to be taken out of the operator's hands?"

J. G. A. Mitchell — "With all the hardware that is available and the confusion about its

application it is difficult to say how the purge should be accomplished. With the string of devices you could set up for assuring safe purging procedures almost any combination is possible depending only on what is required."

M. L. Jones "Well what is a safe purge? How long should it be?"

A. P. Olches "A purge of sufficient duration to insure four air changes in the furnace has been commonly accepted—but lately this seems to have advocates for extending the volume to include the boiler, stack and breeching."

A. W. Hindenlang "Mr. Smith isn't this four air changes some arbitrary figure which doesn't necessarily apply to many furnace configurations?"

J. B. Smith "Not at all. With four successive air changes you would have diluted the original volume of air and gas down to $6^1/_2$ per cent of whatever the original saturation may have been."

M. L. Jones "With a package boiler we disregard the more conventional 30-second purge and use a three-minute purge."

Arthur Dunn "We use 60 per cent of maximum air flow for five minutes on larger boilers."

A. W. Hindenlang "Package boilers represent a different purge problem in some ways. The front corner spaces represent a good portion of the total furnace volume and when you purge you are not always sure you are cleaning these corner pockets. On this basis a small furnace could require a longer or better purge than a larger furnace. Merely time or volume does not seem to be sufficient."

M. L. Jones "Who should tell us the correct purge period or method?"

J. B. Smith "Here is a problem which perhaps can best be solved by the boiler manufacturer—at least the larger ones. Using the new model flow study techniques they should be able to specify proper purge procedures."

A. W. Hindenlang "With model studies verified by spot checks on actual boilers this would seem to be an excellent idea."

Editor's Note: This is precisely the type of discussion we had particularly hoped for—where the problem is well stated, the current confusion explained and a definite and reasonable solution advanced. It appears wholly right and proper that the boiler manufacturer, more than anyone else, must specify what constitutes a proper purge. Cooperation between boiler manufacturers is suggested to avoid even the appearance of making safety a sales issue or bargaining point. Just as different feedwater requirements for different type boilers are set forth by the manufacturer so should it be with purge requirements.

A Solution

Originally we had planned an hour to hour and a half for our discussion. After two hours it was still going strong and

some were just beginning to warm up to the task. But we had to close and Mel Jones set the keynote for the finale.

M. L. Jones — "Can we reach any kind of agreement on the things we want to do? Obviously no two of us want the same devices."

Louis C. Walter — "Do we need what Mr. Hindenlang has asked us—a uniform national code for boiler safeguard systems?"

I wondered whether a uniform national code would be of any value, since so many government agencies, such as state or city, might come into the picture and would be drawing up their own regulations, which would have to be met, but which might conflict with a national code. I feel that probably a national code might be well as a guide, but it would probably have to be modified to meet local regulations.

M. L. Jones — "Sure we need one but we are years away because of individual preferences. We certainly do not want an installation code."

A. W. Hindenlang — "I think we could begin now to build such a code by recognizing that each and every service to the burner and furnace should be protected. By this I don't necessarily mean a trip—protection could be either alarm or trip. Which of these, would be determined by the nature of the plant and operators. Within this framework we would have the flexibility for any type of operation."

C. E. Savage — "Is it economically feasible? We can't make everything damn fool proof."

W. F. Lange — "What about the effect of operators. This should influence how much or what safeguards you need. We all know that in a 3-shift plant very few operators using the same equipment operate it in the same manner. This can be a real problem in trying to establish a code. For example you can establish a desirable prestart purge but can you make each of three operators perform it the same way?"

A. W. Hindenlang — "This could be achieved by arranging the interlock system so that the operator *must* perform the proper functions in the proper order. Failing this the start-up should be aborted."

M. L. Jones — "Well at any rate ASME should take the lead in drawing up this proposed code and as Mr. Smith has pointed out a committee of boiler manufacturers could be a big help."

Editor's Note: With these remarks this session of the Industrial Power Forum was concluded. We feel that these panel members offered much in pointing up some of the areas of confusion surrounding this subject and have given us some suggestions of genuine interest and value toward finding the right road to improved safety in boiler operation.

We shall be interested in hearing from our readers on any of the matters covered here and will endeavor to have the panel members answer any question you may wish to put to them.

PANELISTS' REBUTTAL

Charles Savage — Terminology ought to be standardized and systematized on the basis of function and in keeping with traditional nomenclature. This will simplify consideration of the design and operating problems and provide for logical compartmentation of the component parts. Advertising copy

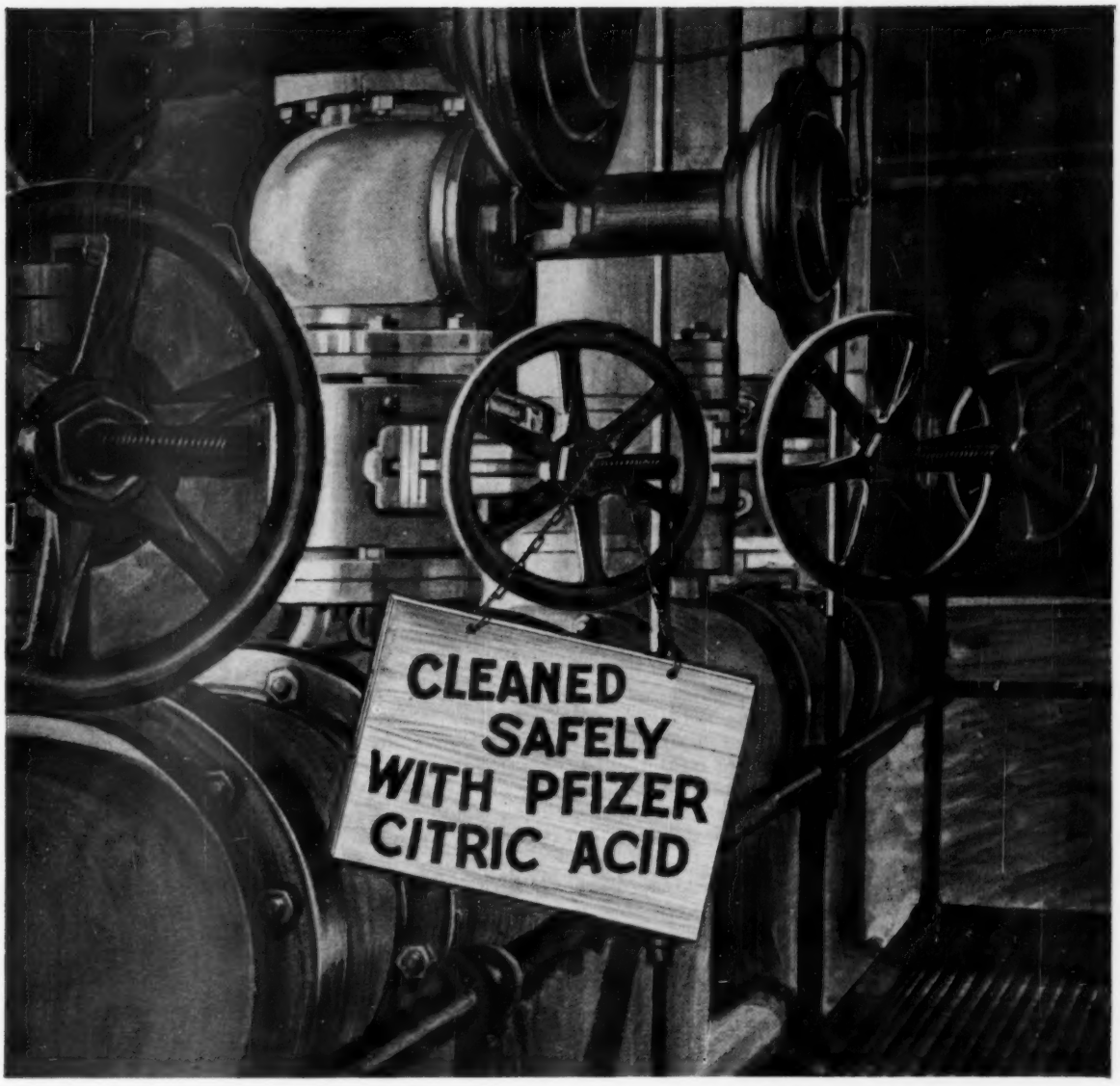
has given us "flame failure protection systems, flame safeguard and programming control, purple peeper, Fireye systems, etc." These vaguely defined systems, modestly originating from simple flame monitoring devices, have grown haphazardly to become the centralized repositories for control of burner ignition and most serious boiler malfunctions. I think that an orderly approach to this mushrooming black box will be aided by considering *total* control of boiler. The modern industrial unit basically has four automatic control systems. I group them as follows:

1. Feedwater Controls
2. Ignition Controls
3. Combustion Controls
4. Safety Controls
   a. Feedwater System
   b. Ignition System
   c. Combustion System

I believe a lot of confusion stems from thinking of automatic burner ignition control systems in terms of safety controls. Physically they may share the same black box and jointly use some components but each has a separate and distinct function to perform. Automated ignition admittedly owes its origin to safety considerations but in function it's a push-button for belly-button substitution in the same sense as feedwater and combustion controls. The function of safety controls is to monitor certain conditions of operation of the boiler feedwater, ignition and combustion systems and shut off fuel for an unsafe condition. As a monitoring system, safety controls should be completely independent of controls on the systems being monitored. Joint use of components in the case of ignition and safety controls may be justified because the ignition control system is not continuously operative but I'm not convinced that this arrangement is right. No clear understanding exists between burner manufacturer and control manufacturer of their responsibilities.

Referring only to the controls and not to the systems being controlled, our boiler safety controls have less reliability than the continuously operative combustion and feedwater controls. "Protection from the protection system" is clearly an objective of design in industrial applications. This comparative low reliability of safety controls is most frequently attributed to inadequate maintenance. When pointing the finger at maintenance, however, it is rarely cited that the design prevented periodic testing of safety controls without tripping the boiler. The so-called maintenance inadequacy is more often than not a maintenance impossibility. Today's industrial boiler has extremely high availability. Maximum utilization of this important asset, particularly in the continuous process industries, requires a design in all boiler auxiliaries and accessories that can be subjected to preventative maintenance without production loss. An excellent example of this type of design is the recently marketed auxiliary burner which permits burner cleaning without production interruption. The design should, of course, restrict access for adjustment of safety controls to prevent tampering. Opportunity exists for control manufacturers to improve performance reliability of their products. The frequent occurrence of "successful failures" in furnace flame detection should inspire use of some of the new technology in reliability engineering that has been developing in rocket instrumentation. More thoughtful furnace design by the boiler manufacturer might simplify flame detection.

Where brief duration loss in steam capacity is of serious consequence to production, it is feasible to provide an annunciator for the safety control system. Time saved in flagging the limit causing a trip immediately by annunciator can be appreciable. Without the annunciator precious time is consumed in analyzing and identifying the cause of tripping before corrective measures can be taken. I think, moreover, that operator error possibilities are lessened with an annunciator. Loss of a boiler firing system compels hasty analysis of the situation and the resultant decision may be wrong, introducing other complications and additional time loss. An annunciator minimizes panic and encourages logical remedial action. Greater use can be made of the annunciator in warning of off-standard conditions in time to permit operational adjustment.



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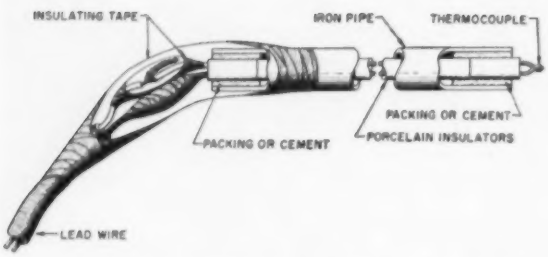


Fig. 1—Simple probe for temperature measurement is shown above

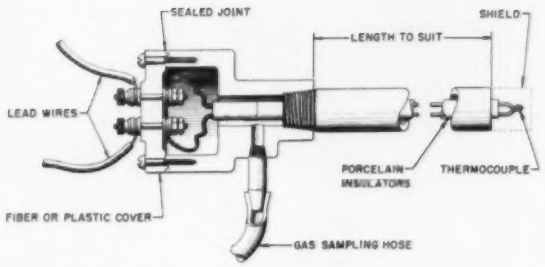


Fig. 2—Combination flue gas flow and temperature measuring device

Testing the Rotary Regenerative Air Preheater—Part II

By JOSEPH WAITKUS*

Air Preheater Corp.

THE easiest and least discussed part of an air preheater test program is temperature measurement. The equipment used is simple and reliable, requires little personal skill, and with attention to a few details, assures an accuracy adequate for the most analytical requirements.

Temperature gradients, much like flue gas composition gradients which we covered in Part I, may exist at both inlet and outlet of an air preheater. Inlet gradient difficulties are few and where found they are generally traceable to the source and distribution of the air at the forced draft fan inlet. (*See* COMBUSTION *March 1960, p. 30*).

The larger the number of points under measurement across a duct area and the quicker the readings are taken the more accurate an average temperature is obtained. Therein lies the problem—how accurate should the results be, what expense is permissible and how much time is available?

Temperature patterns can be measured by many methods. Fig. 1 depicts a simple temperature probe; Fig. 2, a combination temperature flue gas sampler; Fig. 3, a thermocouple grid. The first and second methods have much in common. They are inexpensive, they permit a large number of readings across the duct area but they both require time for the thermocouple to adjust to the new temperature for accurate readings. Both suffer from a slow response and unless conditions across the duct area are stable they cannot give a true average. Both need ample working room for handling and withdrawal of the probe and where long probes are used in hot environments supports, such as shown in Fig. 4, are most helpful in avoiding sagging of the probe itself.

The supports, Fig. 4, should not interfere with the temperature measuring pattern and hence should be so spotted that they lie between points of measurement and are of such design that they produce the least possible disturbance to flue gas flow or air stream behavior. The operator must exercise special care to avoid striking the support members because of physical damage to the exposed thermal junction or an inadvertent grounding of the thermocouple against the probe pipe.

Probe construction of the types in Figs. 1 and 2 consists of a suitable length of iron pipe or steel tubing, usually equivalent to $^1/_2$ in. standard pipe size, with the thermocouple lead wires threaded through so that the thermocouple extends slightly beyond the end of the pipe. At the opposite end tape or a similar holding device keeps the thermocouple from pulling into the pipe. The pipe ends should be sealed against leakage through the probe with a refractory cement. Otherwise under suction in the flue gas stream the outside air siphoned along the thermocouple leads through the probe's length can ap-

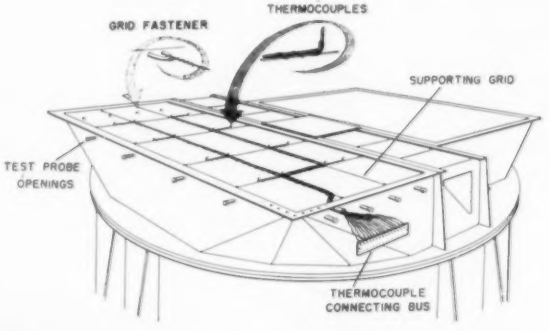


Fig. 3—Thermocouple grid allows for permanent rapid temperature data source

* Manager, Special Applications.

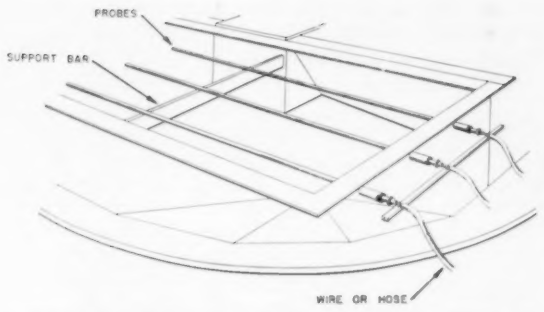


Fig. 4—Probes of Figs. 1 and 3 require certain supports if length is a problem or temperature zone is high

preciably affect the temperature measurements. This effect varies with the position of the junction. With air measurements, since air is usually under pressure, this leakage may not affect measurements. It could cause some inconvenience in the way of a hot air stream into a confined work area.

There is some debate on whether the probe should extend beyond the end of the probe or be shielded slightly within so as not to introduce any error from the radiation effect from duct walls or adjacent surfaces. This effect, in the case of air preheaters, is so small that is of no real importance.

Fig. 2, the combination probe, is an excellent answer to this debate. By continuously aspirating a flue gas sample over the thermocouple leads the thermocouple can be shielded and yet give a most representative temperature measurement.

The third method, Fig. 3, a thermocouple grid, is an excellent arrangement. There are no probes. Measurements can be taken swiftly. The individual thermometers are continuously exposed to their environment and need no adjustment time. The chief disadvantage is that the pattern of test points must be predetermined and remain fixed. Any changes must wait until the steam generator is out of service. This is an expensive method but with reasonable planning it can be made a permanent part of the plant testing facilities. It offers interesting possibilities for regular and rapid observation of temperature performance.

Heavy wire U-shaped hooks have been found an adequate means of fastening the supporting wire grid of Fig. 3. These hooks weld easily and permanently just as do heavy washers welded on edge. The grid wires, of No. 16 BWG bailing wire or equivalent, may be drawn tight without fear of undue tension and yet taut enough to avoid marked grid vibration or shaking in the air or flue gas stream.

Usually the grid wires intersect at the thermocouple locations. If, however, a large number of thermocouples are contemplated this detail may be overlooked and the thermocouples fastened with thin soft wire, above No. 24 BWG, at random points on the grid to suit the desired pattern. This avoids a complicated cumbersome grid.

Below 900 F thermocouples usually employ No. 14 BWG iron-constantan wire and above this level, Chromel-Alumel. The wire gage recommended is heavy enough to assure a rugged thermocouple suited to the requirements of an extended test. For very special investigative work, a finer gage to give greater sensitivity to temperature changes may be selected. In most cases, this is not considered sufficiently important. Greater sensitivity might be useful for the probes in Fig. 1 and 2 where a more rapid adjustment to temperature from point to point can accelerate the measurements

Porcelain bed insulators are recommended if the test will be of long duration; otherwise, asbestos covered duplex wire.

The degree of permanence for the grid will dictate the selection of materials and dimensions for the assembly. Note, the thermocouples cannot be completely shielded without considerable difficulty.

The proper location for a temperature traverse is open to wide discussion and study. Whether to measure close to the air preheater or at remote points depends largely on the plant arrangement and, more importantly, on the duct work configuration and the conditions within. The principal aim is to obtain, as near as possible, the true average of the temperature of the flue gas and air stream. Measurements close to the air preheater are highly desirable. They eliminate the influence of heat lost due to conduction and radiation through the duct work and the drop in temperature due to infiltration or leakage of air into the flue gas stream under negative pressure or suction. On the other hand, with a highly stratified and unstable stream, another location must be selected where the aforementioned losses are likely to be significant. External interferences such as building features and adjacent equipment may prevent a satisfactory traversing of the test area. Here the grid method, Fig. 3, serves advantageously since external conditions can exert no significance.

As with flue gas analysis, Part I, measurements at several points along the length of the stream are highly recommended. Such measurements can spot a trend and, in turn, give some indication of rising or falling values in proper sequence in the direction of flow. For example, if the flue gas outlet stream temperature close to the air preheater is lower than that at a point in the duct some distance away, it can be logically assumed that the test location at the preheater is not a representative one of the true performance of the equipment. Apparently disturbing factors must be present preventing proper measurements.

Heating Surface Metal Temperature

Up to this point we have been considering only the temperature measurements of air and flue gases. There is one temperature measurement, however, which may be interesting to add, although it does not enter into the normal procedure of a performance test. This measure ment is the heating surface metal temperature. It might be considered in the category of experimental research. It holds particular interest for investigators of dewpoint conditions and the relationship to corrosion.

Metal temperature tests were first conducted at the Marysville Station of the Detroit Edison Company in 1945. Several successful tests at other plants followed so that technique and procedure is well established.

Since the heating surface mass is a dense honeycomb structure in continual rotation, special apparatus is required. Fig. 5 illustrates an arrangement developed according to current considerations. Thermocouple wires

are brazed to the metal surface as illustrated in Fig. 6. Duplex solid No. 24 B&S (Brown & Sharpe) gage iron-constantan wire, glass fiber insulated, has been found adequate for the purpose and is easy to handle with reasonable care. To attach the wires to the surface, two holes, about $^3/_{32}$ in. apart are drilled into the element sheet with a No. 60 drill. The wires are inserted, making certain first that they are clean and then fastened to the sheet, using as little flux and metal as can be arranged. With a little practice and care it should be possible to obtain a very neat and tight junction between the individual wires and the metal of the heating surface. The application of a small amount of heat resisting cement to the area around the junction will shield and protect it.

A conduit serves to guide and protect the duplex wire from the thermal junction to the collecting plate fastened against the center post of the rotor. For this purpose, $^3/_{32}$ in. O.D. stainless steel tubing with a wall thickness of 0.02 in. was found satisfactory.

The shorter the conduit, the less chance for difficulties in threading the wire through. However, the length depends on the location of the thermal junction. Be sure in any event to make all conduit bends with a generous radius—not less than 2 in. Braze the conduit to the heating surface sheet in which the thermal junction is provided. Make a direct run from the point where the conduit leaves the heating surface to the collecting plate at the center of the rotor in order to eliminate bends and to shorten the length of the conduit. Even though this places the conduit in the direct path of the flue gas and air flow, the diameter of the conduit is so small that little effect, if any, on flow conditions need be anticipated. If there is any concern over the effect on flow, the conduit may be carried to the nearest rotor diaphram, fastened to it, and then directed to the collecting plate. Consideration might be given to the effect of the soot-blowing jet usually situated at the cold end of the air preheater where the wiring is generally applied.

It is recommended that connecting sleeves be provided near the bend where the conduit leaves the heating surface and near the collecting plate, as indicated in Fig. 5. Pinching the sleeves slightly serves to join the ends of the conduits and make a continuous system for the duplex lead wire. The sleeves should not be pinched, however, until all the wires are threaded up the center of the shaft to the slip rings on top. Thread the wires from the several thermocouples as a bundle through the large conduit and the supporting shaft. After the wires are arranged and fastened to their respective slip ring, and it is certain there are no kinks or breaks in the wiring, the conduit sleeves may be pinched to secure the wiring system in position.

The slip ring is a conventional design, consisting of spring loaded brushes bearing, not too heavily, on disks, one each for the iron and constantan wires. The lead wire for each pair of brushes is directed to a selector switch, which in turn is connected to a recording instrument as illustrated in Fig. 5. As each thermocouple is selected with the switch, a record is made of the temperature changes in a particular part of the heating surface. A typical record of the temperature trends at several points in the heating surface is shown in Fig. 7.

The recorder is a particularly important instrument because of the special characteristics required. It is usually a single point recorder, with a range from 0 to 800 F. A chart speed of not less than 12 in. per minute is recommended. The most important characteristic of the instrument is its sensitivity of response. Changes in temperature must be detected while the surface is moving alternately through the air and flue gas streams at the rate of about 3 rpm on diameters varying from 3 feet to 20 feet or more, depending on the size of unit under test.

Pressure and Draft Measurements

The resistance to flow through the air preheater, expressed as a loss in air pressure or draft in "wg (water

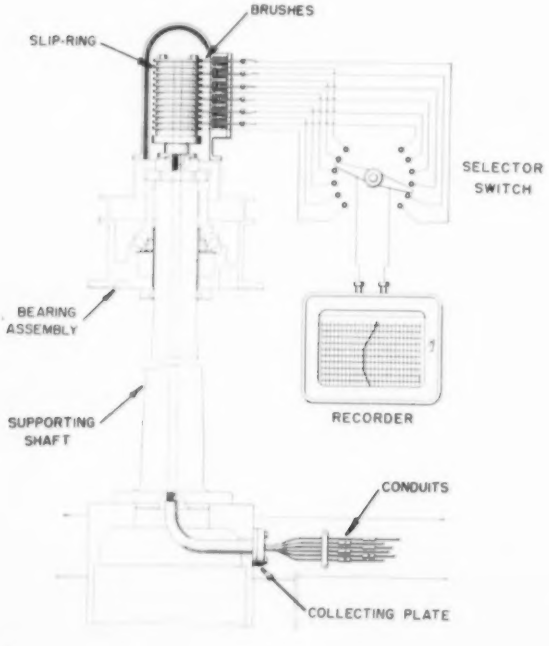


Fig. 5—Special arrangements are needed for heating surface temperature measurements

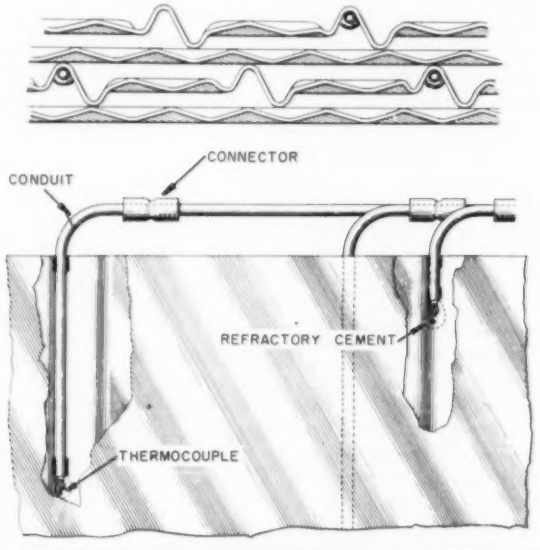


Fig. 6—An example of the precautions cited in Fig. 5 is shown here where thermocouple must be fastened to surface under measurement

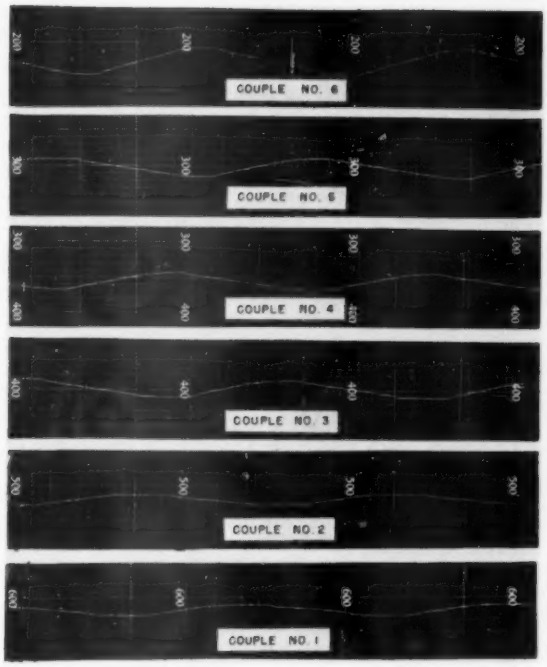


Fig. 7—A typical record of temperature trends is pictured here and was employed in Part I

gage), is an important part of the performance test and requires some particular considerations. The measurements are influenced and quite often confused by the flow conditions at the point where the measurements are taken. The ideal state, of course, is streamlined flow, with complete absence of any form of turbulence. This, unfortunately, cannot be attained because of the configuration of the ductwork with changes in cross-section, bends and offsets. The result is that measurements are disturbed by a combination of static pressure and velocity pressure aspects.

Since only static pressure measurements are desired, it is necessary to consider special precautions to avoid the influence of the velocity or impact aspect of flow. This has been achieved quite effectively with the special tube illustrated in Fig. 8.

A narrow circular groove protects or shields four small orifices leading to a plenum chamber. The design develops the equivalent of a filtering action, reducing the effects of velocity pressure likely to reach the manometer through the tube from the plenum chamber. The liquid level in the manometer remains comparatively steady and is therefore easier to read. What little vibration there might be in the manometer level is largely the result of pulsations in pressure induced—at least at the outlet of the air preheater—by the air pre-heater rotating element.

An interesting characteristic of the static pressure tube is that it functions accurately through a wide angle of incidence to the direction of flow of the stream. In other words, turbulent flow or impact from practically any angle against the tube will not effect the measurements. Only static pressure reaches the manometer.

One drawback in the static tube design is the tendency for the small orifices to plug in dusty gases. This may necessitate removal for cleaning, or a blowback purge with compressed air while in place. The frequency varies with the condition of the gases.

Manometers or "U" gages are the standard indicating instruments for drafts and air pressures. Water is preferred to mercury because of the ease with which it can be handled aside from the fact that the measurements are most generally of a comparatively small magnitude and with water a generous difference in level is obtained.

In arranging the manometers it is recommended that both the inlet and outlet of the air preheater be measured on individual instruments with the difference or loss indicated directly on a third manometer. Although the readings from the individual manometers can be subtracted to obtain the draft loss or pressure loss, as the case may be, the direct difference may be easier to record because of steadier levels in the manometer. If the direct reading is unsteady, it may be the result of fluctuations created by some unbalance in the air preheater—probably uneven distribution or accumulation of heating surface deposits—or an opening in rotor sealing members.

Probing the duct area for draft and air pressure measurements is just as important as in the case of flue gas analysis and temperatures. The more readings taken, the nearer the average approaches the true condition in the area under test. It is a mistake to rely on spot readings because conditions in the duct with respect to distribution and flow are continually changing. Simultaneous readings at the inlet and outlet, recorded as rapidly as possible, are essential to a good test of performance.

The selection of the areas to test is again an important consideration. The ideal location is, of course, within the air preheater structure because guarantees on resistance are so based. Losses due to extra duct length, bends or turns, changes in shape or cross-section, leakage or infiltration, must be ruled out of the measurements insofar as air preheater performance is concerned. If for any reason measurements must be taken at remote points from the unit, then the results should be studied with consideration for the influence such factors as mentioned may have on the results. Additional test areas may be necessary to establish the effect on the overall results.

Numerous attempts have been considered and made to measure the flow through the air preheater by means of pitot tubes of various types. Most of the attempts failed to give reliable results, for the reason that the basic requirements for such measurements did not exist at any point in the duct system. Rarely is it found that flue gas and air ducts provide the necessary length—before and after the point of measurement—to assure some reasonable degree of stability or streamlined flow. The duct system is most generally designed for the shortest possible connection between components of the plant. The situation is aggravated by the need for bends, changes in cross-section, and offsets at various points in the system to produce a compact plant design.

The best possibilities for flow measurements by pitot tubes are sometimes found in the air outlet or hot air duct system. Usually this duct, connecting the air preheater with the windbox of the steam generating unit, is long and maintains a uniform cross-section for somewhere near the required length. Only then is it recommended that the pitot tube measurements be included as a part of the test to check flow quantities calculated from the analysis of flue gases and measurement of temperatures.

As a matter of passing interest, it might be pointed out that two types of pitot tubes, illustrated in Fig. 9, are available. One is the well-known "combined-impact type," and the other, less known but equally as good, is the "combined-reverse type." The latter type is preferred because it is easier to handle, requiring a comparatively small opening for straight insertion into the duct. The former type is difficult to handle and requires a large opening in the duct to accommodate the bend in the tube. All factors considered, the "combined-reverse type" is the most practical tube and is therefore most generally adopted for quantitative measurements of flow in and out of the rotary regenerative air preheater where duct conditions, with respect to design and arrangement, permit such measurements.

Complementary Data

The measurements discussed to this point will indicate to a certain degree, the performance of the air preheater. However, to make the test complete and of more general value, additional information is required. This additional information is usually found not within the area of the air preheater but at sources remote from the equipment—for example, the panel board of the steam generating unit and in the analytical laboratory.

A modern steam generating unit is most generally equipped with recording and indicating instruments covering every important item of performance, including much of the data as can be obtained from panel instruments be tabulated as a part of the test program. The following items might be recorded.

Steam flow, lb./hr.
Feedwater temperature inlet, °F
Feedwater temperature outlet, °F
Gas temperature—boiler outlet, °F
Gas temperature—air preheater inlet, °F
Gas temperature—air preheater outlet, °F
Air temperature—air preheater inlet, °F
Air temperature—air preheater outlet, °F
Air temperature—windbox, °F
Draft—furnace, in.
Draft—air pressure inlet, in.
Draft—air pressure outlet, in.
Draft—stack, in.
Air pressure—air preheater inlet, in.
Air pressure—air preheater outlet, in.
Air pressure—windbox, in.

The quantity of fuel consumed can usually be obtained from coal scales or from flow meters in the case of oil and gas fuels. The ultimate analysis of the fuel is an item of considerable importance. For this information follow test code procedures to accumulate samples for analysis covering the period of the test.

The humidity of the air admitted to the forced draft fan has some significance in the calculated analysis of the test data. Obtain wet and dry bulb temperature readings close to the fan inlet as periodic intervals during the test.

The recording of panel board data may appear a duplication of the measurements obtained at the air preheater. This is true to a certain point, but the data are an excellent check on trends as the test progresses, furthermore, the test data are a check on accuracy of the panel instruments. Measurements at the air preheater are more accurate due to the special precautions taken to obtain them and it may be found that the panel instruments need readjustment.

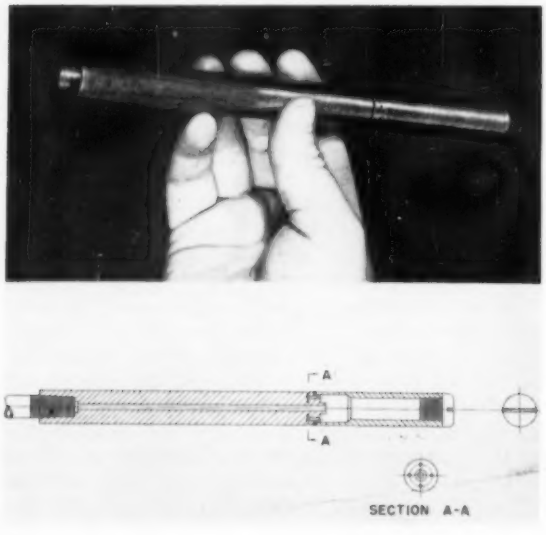
Conclusions

To summarize this detailed account on testing of the rotary regenerative air preheater to determine its actual operating performance, one might emphasize the following:

1. Decide whether the test is intended as a routine operation, as a proof of performance, or as a prelude to an investigation of some phenomenon or condition.

A. For a *routine test*, a number of refinements mentioned can be overlooked and emphasis placed on getting reasonably reliable and constant measurements in the shortest possible time Probes can be used generally with measurements taken at some selected point in the duct area, initially determined by precise tests, as the location nearest to the average for that area.

B. For a *proof of performance* an elaborate test should



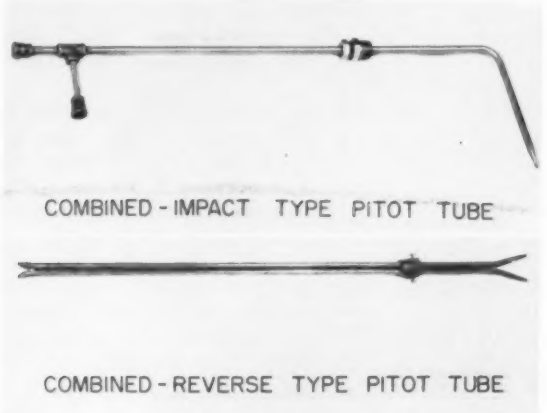


Fig. 9—Two types of pilot tubes are shown here. Their use represents a problem since they work only in areas of uniform cross-section

←

Fig. 8—A special tube has been devised for static pressure measurements in a moving gas stream

be considered with all factors measured that bear on or influence the results. Do not undertake a test program to prove performance unless there is every desire and intention to plan and conduct a complete test.

C. The *investigative type of test* is subject to some latitude depending on the nature of the investigation and the results desired. Usually it is important enough to make as many refinements as possible and conduct the test with the same meticulous care exercised for a proof-of-performance test.

2. Layout the entire physical arrangement of the plant applying as much detail as possible to guide the selection of test areas. The layout should include not only the arrangement of the equipment adjacent to the air preheater, but the cross-section of the areas considered suitable for testing. It should furthermore, point out any obstructions or interferences limiting testing areas.

3. Study the arrangement of the equipment for distribution and flow factors important to obtaining average or representative results.

4. Select at least one check point or area in the outlet duct systems for comparison with results taken close to the air preheater.

5. Do not conduct a test for less than four hours. Plan in terms of an eight hour test. The more irregular the steam flow conditions or load on the steam generating unit, the longer the recommended test period.

6. Arrange for simultaneous readings at the inlet and outlet of the air preheater for all measurements.

7. Organize the test with all considerations for the personnel requirements. The physical aspects of instruments and general equipment require their particular consideration, but the personnel considerations are equally as important to a successful test.

A. The ideal arrangement provides a man for each instrument and measuring station. This, of course, requires a large staff, and is expensive.

B. Double-up on the duties, when those duties and locations are reasonably close. Assign men to work on one plant level and performing nearly the same duty at two or more stations as conditions permit. For example, it is not considered good practice for a man to alternate between a potentiometer and an orsat. Keeping the men engaged in separate like functions, (including the moving of probes from one point to another in the ducts), a better organization and smoother functioning test will result.

C. Have a relief man qualified for any station in the test. It would be fortunate to have a man experienced to handle any instrument or device. However, this may be difficult to arrange and for that reason several men may be required to fill the needs at unpredictable moments.

D. Have man in complete charge of the test and free to circulate the entire plant, observing the resalts obtained at each station, and, more important, detecting any change in the operation of the steam generating unit which might upset the continuity and reliability of the test.

It is the author's hope that in this general description, sufficient practical information has been disclosed to clarify the procedure for conducting a performance test of a rotary regenerative air preheater. It is by no means a "cut and dried" or well-defined activity. Each installation must be studied for its particular limitations in the light of the requirements and results desired. The procedure is a little more complicated than for conventional types of tests. There seems to be no limit to the amount of care to exercise in order to obtain satisfactory results. It is obviously a case of achieving a clearly defined objective with the combination of a generous study of the plant arrangement, application of sufficient and adequate instrumentation, and the assignment of enough personnel to record the performance of the equipment. Overlook or minimize any of these factors and the test is likely to be incomplete and probably inaccurate.

Urge Utilities to Lay Claim to Industry Research

America's electrical manufacturing industry is carrying on a research program "second to none in the nation" and utilities supporting the effort should take proper credit for this work, the president of Westinghouse Electric Corporation has urged.

Speaking at the annual meeting of the Southeastern Electric Exchange, New Orleans, La., April 7–8, Mark W. Cresap, Jr., invited executives of the electric utility industry to join with electrical manufacturers in a program to acquaint the public with the nature and scope of the industry's unequaled research program.

"People have come to think of electric power as a steady, stable, reliable, dependable industry," Mr. Cresap pointed out. And while the industry values that attitude and has worked hard to earn it, he said, "those words 'steady, stable, reliable, dependable' give an essentially incomplete picture of the electric power industry today. They do not describe an industry which right now has more new, significant and exciting developments going on than at any other time in this century."

The Westinghouse president said this should be regarded as an opportunity to show that utilities are members of a progressive, research-minded industry.

"The strongest point in your favor is one simple, indisputable, overriding fact: the electric power industry has conducted a research program second to none in the nation," he emphasized. "This industry is not merely keeping up with the times in research—it is so far ahead of the times that it may truly be said to be creating the times."

The electrical manufacturing industry employs a greater number of scientists and engineers than any other industry and devotes a larger percentage of its sales dollar to research and development than any other industry. Only the aircraft and missile industry uses more scientists and engineers in research and development.

High-Purity Water Made Possible with Nalcite Ion Exchange Resins

Dresden Boiling Water Reactor System has Unusual Demineralization Needs

Water purity in a degree not even considered a few years ago is required at the Dresden Plant of Commonwealth Edison Company in Northern Illinois. Nalcite Ion Exchange Resins have been chosen for the condensate high flow, reactor cleanup, and waste treatment demineralization units, one of which has an unusual system for removal, regeneration and re-placement of exchange resins.

Condensate High-Flow Demineralizer

2,800 gpm condensate, returning to the reactor from the turbine condensor, passes through the primary system demineralizer at flow rates of 70 gpm/sq. ft. of bed area. This demineralizer is designed to remove more than 1,000 lbs. of dissolved and suspended impurities from the condensate each year.

Resin Removed for Regeneration

To prevent cross-connections between the reactor and regeneration piping, equipment was developed for external regeneration of the ion exchange resins. This is accomplished by semi-fluid pressure transfer.

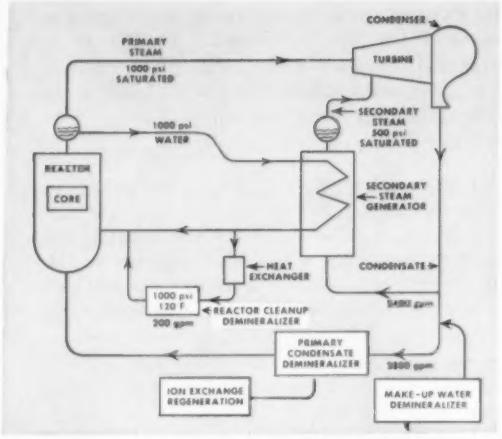
Nalcite HCR-W and SBR-P in the primary condensate demineralizer have the high degree of sphericity and ion exchange ability essential to high flow rate service at minimum pressure drop. They also have the resistance to attrition which permits resin transfer from the demineralizer to separate regeneration units and back, repeatedly . . . without measurable bead breakage.

Reactor Cleanup Demineralizer

The reactor cleanup demineralizer on the return side of the secondary steam generator system handles 200 gpm condensate at 1000 psi, 120° F. On-line and standby units have flow rates of 10 gpm/sq. ft. of bed area. Exhausted resins are radioactive, and are replaced with new resins, rather than regenerated.

Waste Treatment Demineralizer

Radioactivity in wastes is concentrated by the waste treatment demineralizer. Exhausted resins are radioactive and are sluiced from the units and prepared for disposal.



Simplified diagram of the Dresden Boiling Water Reactor steam condensate system. Nalcite resins are used in condensate high flow, reactor cleanup and waste treatment demineralizing units.

Make-Up Water Demineralized

Very small quantities of make-up water are required, due to painstaking design to eliminate condensor leakage, and other system losses. Conventional demineralizers, followed by mixed-bed polishers, provide make-up water.

Ideas for the Future

While operating temperatures and pressures at the Dresden Plant are nominal in modern steam generation practice, the special requirements for high flow and water purity from demineralizers in the steam-condensate system may have practical application outside nuclear reactor technology. It is significant that Nalco had ready, in Nalcite HCR-W and Nalcite SBR-P, ion exchangers which make possible these unusually severe ion exchange applications.

Ideas for Today

For busy engineers and technical men, Nalco has prepared concise data on water conditioning with Nalcite cation and anion ion exchange resins: Bulletins Z-12 and Z-13, free on request. If you want fast action on a specific water treating problem, Nalco experts are available on short notice. Call or write.

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Ion Exchange Division
6234 West 66th Place — Chicago 38, Illinois

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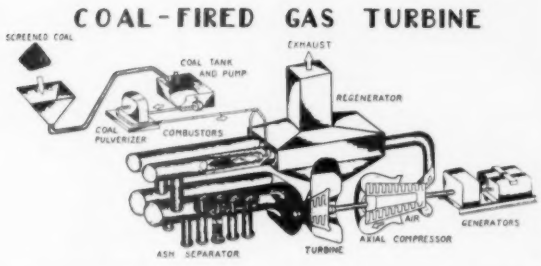

Fig. 1—Schematic of the 3750-hp coal-fired open-cycle gas turbine of the Locomotive Development Committee now the U. S. Bureau of Mines

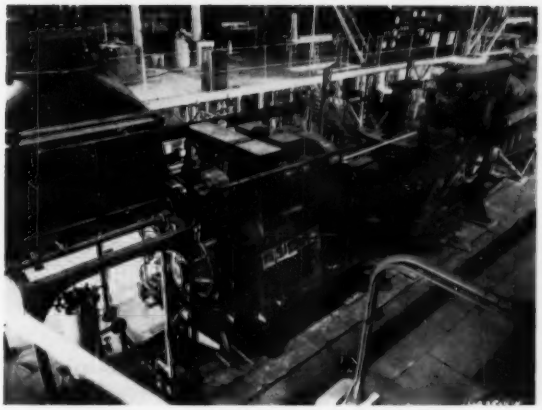

Fig. 2—The unit in Fig. 1 is shown in its partially assembled state during its erection at Bureau's Coal Research Center at Morgantown, W. Va.

By JAMES P. McGEE* and RICHARD C. COREY†

Bureau of Mines Bureau of Mines

Bureau of Mines Coal-Fired Gas Turbine Research Project

The U. S. Bureau of Mines accepted the offer of the Locomotive Development Committee's coal-fired, open-cycle gas turbine when the Dunkirk project was terminated. Here is the first report on the Bureau's plans and the set-up at Morgantown, W. Va.

FOR several years the Bureau of Mines, U. S. Dept of the Interior, has been interested in a comprehensive research program directed toward development of a coal-fired, open-cycle gas turbine, which is the simplest and most compact system. Although the potential advantages of such a turbine are well known, the most significant ones bear repeating here, namely, an expanded use of coal, and a realization of the unique advantages of various combined thermal cycles for central-station and industrial power plants burning coal as the primary fuel. The Bureau has not had sufficient funds to undertake research of the scope considered necessary to develop a coal-fired gas turbine within a reasonable period of time. Moreover, the Bureau has had no desire to engage in work that might duplicate an experimental program of the Locomotive Development Committee (LCD) of Bituminous Coal Research, Inc., which until recently had been working intensively at Dunkirk, N. Y., to develop a coal-fired, open-cycle gas turbine for locomotives.

However, in 1959 two circumstances led the Bureau to plan and partly execute a comprehensive gas-turbine research project directed primarily toward use in electric utilities and industrial plants. First, the Locomotive Development Committee terminated its Dunkirk project for adapting to locomotive use, a coal-fired, open-cycle gas turbine, and offered the experimental equipment to the Bureau for further research. The Bureau accepted this opportunity to carry out additional studies, which presented a chance to gain knowledge and experience with one of the chief problems related to coal-fired turbines—controlling the deleterious effects of the mineral matter in coal on turbine components. This research would be valuable in developing further the locomotive and marine applications of the coal-fired gas turbine. Accordingly, the turbine and auxiliary equipment were transferred early in 1959 to the Bureau's Coal Research Center, Morgantown, W. Va. Second, a shift in emphasis on the Bureau's coal research program made it possible to schedule these studies.

A schematic diagram of the 3750 horsepower turbine is shown in Fig. 1, and the partially assembled unit at Morgantown is illustrated in Fig. 2.

Current Gas-Turbine Technology

Present central-station and industrial practices afford relatively high availability and thermal efficiency from conventional thermal power cycles because of the remarkable design improvements that have been made in boilers and steam turbines and the progressive trend toward higher steam pressures and temperatures, steam reheat, and so forth. Therefore, the goals for thermal cycles that include the gas turbine are well defined. Con-

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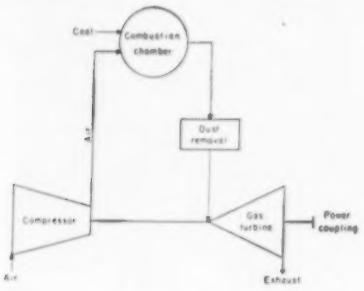

Fig. 3—The direct fired gas turbine which enjoys the simplest cycle from a design standpoint

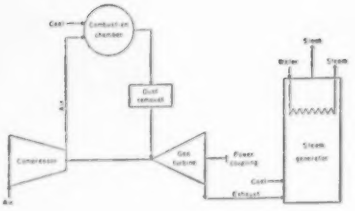

Fig. 4—The gas turbine of Fig. 3 is pictured here here with its exhaust used as a source of boiler preheated air

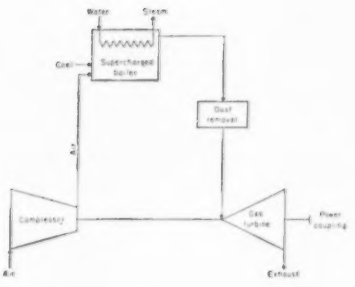

Fig. 5—The boiler firebox is pressurized in this design with the hot combustion gases expanded in the gas turbine

cerning the gas or oil-fired, gas-turbine steam-turbine cycle, some notable advances have been made. A General Electric Company study of a group of units (1)[1] showed 98.1 per cent service time, 80 per cent use factor, and only 0.7 per cent shutdown. Under the severe conditions imposed by residual-oil firing and intermittent loading, combustor linings lasted 3000 to 5000 hr, fuel nozzles over 10,000 hr, first-stage nozzles 5000 to 10,000 hr, and second-stage nozzles, turbine buckets, and turbine wheels lasted over 20,000 hr. Even as a maximum goal, this performance is a challenge for an open-cycle coal-fired turbine, the blades of which must withstand the erosive, and in some instances, corrosive effects of ash and other constituents derived from the mineral matter in coal.

POSSIBLE METHODS OF UTILIZING COAL IN GAS-TURBINE SYSTEMS

The following are recognized as possible methods of using coal as a gas turbine fuel:

I. Direct firing
   - A. Complete combustion in the open cycle
   - B. Gasification of coal, with direct firing of the producer gas in the combustor
   - C. Carbonization of coal, with direct firing of the carbonization gas in the combustor

II. Indirect firing
   - A. The closed cycle
   - B. The exhaust-heated cycle

In addition, there are two combinations of the steam and gas turbine of interest for coal firing:

- A. Exhaust heat recovery, with the exhaust from the gas turbine used as combustion air for the boiler
- B. Use of the gas turbine to pressurize the firebox of a steam boiler

Therefore, at least seven methods of utilizing coal as a fuel for a gas turbine, either alone or with a steam turbine, are possible. Since none of these schemes are novel, and all have received varying degrees of study, we will not go into detail, but merely enumerate them and some of their attendant problems.

1. Direct-fired gas turbine, Fig. 3.—This cycle is the simplest from the standpoint of design, but the thermal efficiency is comparatively low. However, the efficiency of the cycle can be improved by the addition of intercooling, reheating, and regeneration.

2. Gas turbine with exhaust-heat recovery, Fig. 4.—This cycle, which combines the steam turbine and gas turbine, offers a potential reduction of 3 to 6 per cent in the heat rate compared with that of a steam turbine plant of comparable size (2). Plants fired with oil and natural gas are in commercial operation but coal-fired installations have yet to be demonstrated. The exhaust from the gas turbine is 800 to 850 F and contains approximately 17 per cent oxygen, making it an excellent source of preheated combustion air for the boiler. The load distribution is approximately 87.5 per cent to the steam plant, and 12.5 per cent to the gas turbine.

Since the gas turbine operates on the open cycle, ash and coke particles must be removed before the hot gases enter the turbine; so the problems are essentially those of the direct-fired gas turbine.

3. Gas turbine with supercharged boiler, Fig. 5.—In this system, the boiler firebox is pressurized with air from the gas-turbine compressor; the hot combustion gases from the boiler is expanded through the gas turbine (3). The gain in thermal efficiency is 4 to 8 per cent, depending upon the overall efficiency of the steam plant under comparison (4). The percentage of total power generated by the gas turbine ranges from 14 to 17 per cent, with the higher figure typical of small plants.

The advantages claimed for this system include:

- (*a*) Improvement of plant efficiency over a steam plant, regardless of the size or operating conditions of the latter;
- (*b*) Reduction of boiler and building sizes, pointing to reduced installation costs;
- (*c*) Reduction of water requirements for condensers and boilers;
- (*d*) Reduction of the size of auxiliaries.

4. Gas turbine with exhaust-heated cycle, Fig. 6.—

[1] Numbers in parentheses refer to similar numbered items in the List of References at the end of the article.

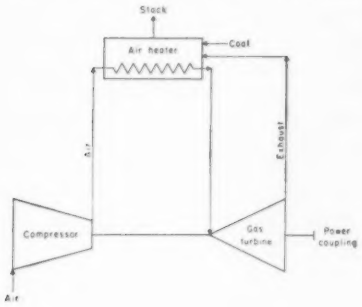

Fig. 6—The exhaust-heated cycle heats compressed air by coal and uses the exhaust for combustion air in the preheater

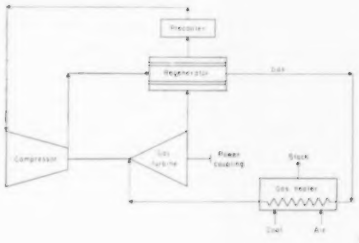

Fig. 7—The closed cycle turbine is shown here. This is the only cycle the commercial gas turbines now use

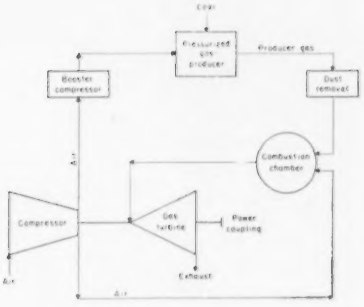

Fig. 8—This is a special adaptation and has the coal gasified in a pressurized gas producer with hot product gases used to drive the turbine

The exhaust-heated cycle incorporates a combination of external heating with internal combustion (5). Air from the compressor is heated to operating temperature and then is expanded in the turbine. At 800 to 850 F, the turbine exhaust is a source of combustion air for firing the coal in the preheater.

The advantage of this cycle is that the turbine is driven with clean air. The disadvantage is the relatively large heat exchanger, which must be constructed of expensive alloys (6).

5. Closed-cycle gas turbine, Fig. 7.—In this system the gaseous working fluid is heated indirectly. Of interest in passing, the only commercial coal-fired gas turbines use the closed cycle (7, 8).

The principal advantage of this cycle is that the absolute pressure of the working fluid may be elevated, thus permitting a considerable size-reduction of the rotating parts and the heat exchange equipment. Closed-cycle turbines have been proposed for use with air, nitrogen, helium, and carbon dioxide, illustrating that there is also more freedom in the choice of the working fluid.

Due to pressurization of the gas, good heat transfer is obtained, and over 50 per cent of the total heat added to the working fluid is transferred in the regenerator. The high-temperature gas heater is the major problem.

6. Gas turbine with producer gas firing, Fig. 8.—In this system, coal is gasified in a pressurized gas producer, and the hot product gases are burned to drive the turbine. The pressure produced by the compressor of the gas turbine—5 to 9 atmospheres—allows high gasification rates with low carryover from the producer (9).

Most of the coal ash is removed through the grate, so the separation requirements are less severe than for direct firing. The gas stream, which must be dedusted, is approximately 10 per cent of the total flow to the turbine. Coal feeding to Lurgi-type pressurized producers operating at considerably higher pressures than are required for the gas turbine plan is common practice.

The major problem appears to be operating stirrer arms to keep the pressure drop through the fuel bed as low as possible when operating with caking coals. While producer operation with bituminous coal at atmospheric pressure is well developed, the caking problem increases with increased pressure of operation.

7. Coal carbonization cycle, Fig. 9.—This is the latest scheme, proposed by Foster-Pegg (10), for adapting coal as a fuel in a steam turbine-gas turbine power plant. All the coal is carbonized in a fluid-bed type of operation, and the carbonization gas, containing tar vapors, is dedusted, then burned in the combustion chamber of the gas-turbine plant. The char from the carbonizer is used as boiler fuel, and the exhaust from the gas turbine serves as preheated air for the combustion of the char. The carbonizer is operated at a slightly higher pressure than is required for the gas turbine. This necessitates a booster compressor for the combustion air to the carbonizer. Grinding the char, hot and at pressure, has been proposed.

Combustion of the char in cyclone-type burners is a possibility. However, the relatively high operating pressure (40 to 80 in. of water) is reflected in a high backpressure on the gas turbine.

Operation of commercial-size fluidized carbonizers for coking coals and development of pressurized char grinding appear to need further development.

Bureau Program

The Bureau of Mines research program includes a comprehensive study of methods for minimizing erosion

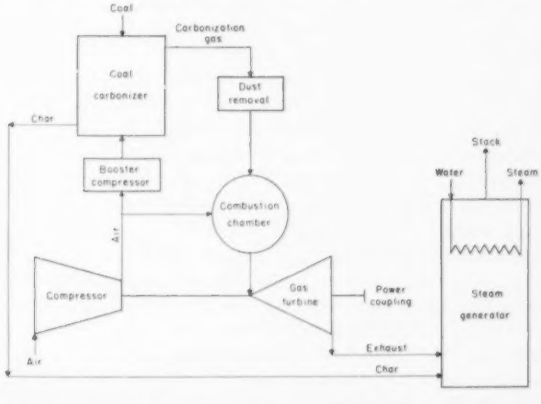

Fig. 9—Most recent scheme for adapting coal in a steam-turbine gas turbine plant uses a fluid bed to carbonize the coal and the deducted carbonization gas is burned in combustion chamber of the gas turbine plant

of the turbine blades by solids in the combustion gases. Possible solutions to the erosion problem include:

1. Reducing sufficiently the concentration of solids in the products of combustion so that the erosive effect on the blades will be negligible;

2. Reducing both the concentration and the particle size of the solids, since there is some evidence that if the particles do not exceed a certain size, erosion will be less severe;

3. Examining the aerodynamics of the gas turbine in the light of the experiences of the Locomotive Development Committee, and designing the blades and gas paths through the turbine to minimize the effects of gas-borne solids. Of course, removal of substantial quantities of solids, and consideration of particle size still would be necessary, but the specifications in these respects might be less restrictive with a better aerodynamic pattern for the gases;

4. Selection of best blade alloy from the standpoint of erosion resistance, consistent with optimum strength and ductility.

None of these proposed solutions consider the possibilities of poor performance due to corrosion of blades by the mineral matter in the coal, or deposition of coal-derived solids on the blades. Although these phenomena were not experienced during the LDC experiments, they cannot be eliminated from consideration. For example, peat-fired gas-turbine experiments in Australia with a 75-kw Ruston and Hornsby 3CT unit (11–16) demonstrated that erosion can occur under certain conditions related to the composition of the mineral matter in the fuel, the maximum temperature attained during combustion, and the velocity and the size of the particles. Furthermore, an excellent summary of the role of fuels in gas-turbine technology (17) refers to British research with the open-cycle coal-fired gas turbine, in which corrosion and deposition (fouling), rather than erosion, were the principal problems. Therefore, there is no *a priori* reason to assume that direct firing of American bituminous coals would not present the same problems.

Immediate Phase of Program

The gas turbine to be used in the Bureau of Mines development program will utilize the direct-fired cycle.

Plans call for a complete turbine reblading program comprising four steps which will be carried out in cooperation with the Gas Turbine Division of the General Electric Company. The objectives of the reblading program are twofold: First, design a blade path that will minimize erosion of the rotor blades by coal ash, and second, select suitable blading materials.

Since no major changes are contemplated in the existing multiple-cyclone type ash-removal system during the initial test run, we assume that the total volume of ash passing through the turbine will be approximately the same as in the last 1100-hr run performed by LDC. While the blade erosion during this run was considerably less than in previous tests, the wear was concentrated at the root of the leading edge of the rotor blading. Fig. 10 shows the erosion pattern in the third-row blade.

Of interest to note, the blades in the first row were virtually free of erosion. If a blade path can be designed that will distribute the erosion more or less evenly over the entire blade length, or achieve a balance between erosive action and blade deposition, or concentrate more of the wear at the lightly-stressed outer perimeter, we believe that the operating time of a set of blades can be significantly increased. The ultimate aim of the Bureau is to achieve about 50,000 hours' availability. The following program has been devised:

1. Study the aerodynamics of the turbine blading, both stationary and rotating, to determine—quantitatively, if possible—the causes of the character of the concentrated erosion, including the effect of any concentration of ash due to radial transport through boundary layers, wakes, or separation.

2. Design the turbine blades to minimize erosion, considering such factors as impingement velocities and concentration of ash, and make working drawings of a recommended design. Also, conduct a study of abrasion-resistant materials suitable for turbine blades.

3. Manufacture turbine blades based on the design mentioned in item 2.

4. Assemble blades in the rotor and stator, grind the tips to the required tolerance, and balance the rotor.

Initial Test Run

When repairs, replacement of parts, and final adjustments are completed, we plan to operate the turbine progressively for 1500 hr to test the new blading design. Tentative operating conditions are:

Turbine gas-inlet temperature, F	1250 to 1300
Turbine rpm	5000 to 5400
Turbine net power output, hp	3000 to 3500

Having the same characteristics as the Pittsburgh-seam coal used by LDC, the fuel burned in the turbine will have a proximate analysis, on a dry basis, as follows: Ash 6.5 per cent, volatile matter 39.5 per cent, fixed carbon 54.0 per cent. The coal will be sized to $^{3}/_{16} \times 0$ in., pulverized to 90-per cent-through-200-mesh, and then fired in the combustors of the turbine.

Long-Range Objectives

The 1500-hr test run is designed to determine what can be done to design blades capable of long life when ex-

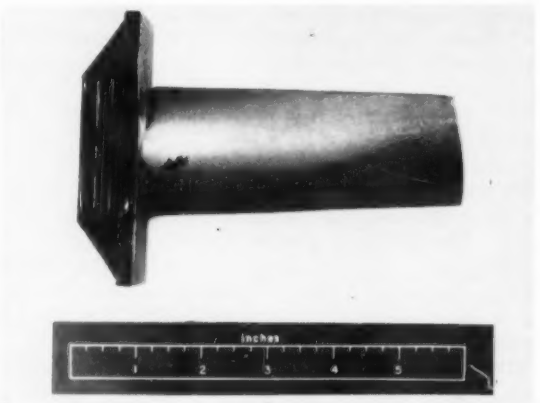

Fig. 10—This is the root section of the third row blade in the experimental turbine of Figs. 1 and 2. It shows the blade erosion after the last 1100-hr run at Dunkirk by the LDC. Note the wear is concentrated at the leading edge

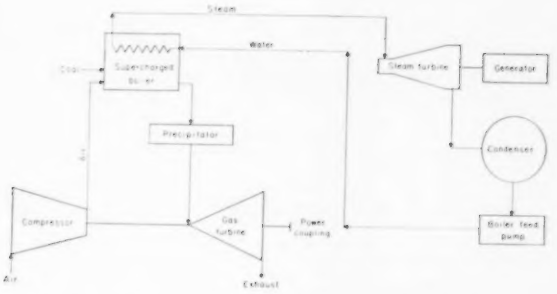

Fig. 11—The idea of applying an electrostatic precipitator to the open-cycle gas turbine is expected to give excellent results

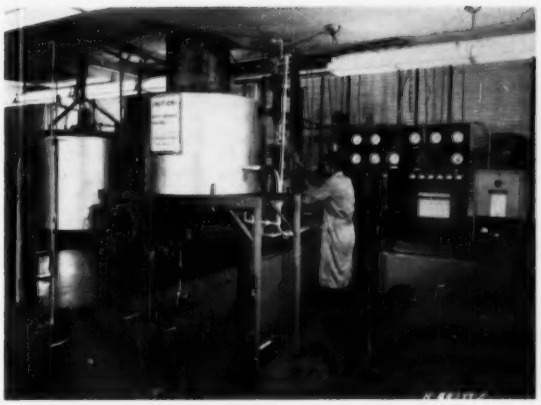

Fig. 12—To adapt the precipitator to gas turbine work calls for studies at 80 psig and 1500 F. Bench scale unit above will be tested under these conditions

posed to dust concentrations expected at the outlet of dust separators. However, considering the gas turbine for use in stationary plants, where space limitations are less restrictive than in locomotive applications, there are other phases of the turbine process, which the Bureau also hopes to investigate in order to attain the overall objective of turbine availability approximating 50,000 hr with negligible forced outages. Two such phases are the separation of ash from the hot gas stream and the improvement of combustor operation.

Ash Separation

If the gas can be suitably cleaned before it enters the turbine, any manufacturer's standard turbine design can be used. While this may be oversimplification and the solution to the problem of blade life may be a combination of blade design and improved gas cleaning, the latter approach will be vigorously explored. It is evident that LDC did an excellent job of developing mechanical ash separators, as evinced by the continually improved performance of their "Dunlab" separator. Continued development of the separators to reduce the amount of blowdown gas and, if possible, minimize the pressure drop across the cyclone still further, would result in increased turbine efficiency. To remove fine particles, however, the electrostatic precipitator is superior to the centrifugal type, and pressure drop through electrostatic precipitators is much less, which is reflected in a higher efficiency in the gas-turbine cycle. Thus, we believe that in any layout with sufficient space, the use of the electrostatic precipitator offers considerable promise for an open-cycle, coal-fired gas turbine.

Almost all central station units now being built make use of an electrostatic precipitator to clean up the stack gases. Therefore, it would seem logical to install the precipitator in a coal-fired gas turbine plant in such a location that a technical advantage can be realized in addition to maintaining good public relations. A proposed installation of this type is shown in Fig. 11.

To adapt an electrostatic precipitator to the gas-turbine system requires that this equipment be capable of operation at pressures up to 80 psig and temperatures to 1500 F. Although such equipment is not commercially available, several manufacturers have signified a willingness to undertake the development of precipitators to meet these conditions. To investigate the characteristics of precipitators operating in the range of temperature and pressure stated, the Bureau of Mines has set up and is testing a bench-scale model, Fig. 12.

Combustor Operation

Since space is not a primary factor in stationary-plant installations, more freedom in combustor dimensions is possible. Operating with 95 per cent combustor efficiency with a coal containing 6 per cent ash means that almost one-half of the extraneous material in the gas to the dust separators would be abrasive coke particles. Raising the combustor efficiency would decrease the concentration of solids to the separators and, at the same time, improve overall plant efficiency. Larger combustors with correspondingly increased gas residence time for a given firing rate should improve combustion efficiency.

Conclusion

Development of a coal-fired open-cycle gas turbine capable of operating 25,000 to 50,000 hr without excessive forced outages for reblading or other expensive repairs will depend largely on well-conceived and coordinated basic and applied research directed toward minimizing the erosive and corrosive effects of the mineral matter in the coal. The principal research efforts must be conducted to determine (*a*) the optimum geometry of the blades and gas passages, (*b*) the best design of the combustor and burners to achieve maximum combustion efficiency and optimum flame temperature, and (*c*) permissible concentration and size of the particulate matter in the gases entering the turbine. There are numerous variables to be considered in the overall program; for example, the optimum coal fineness, dust-collector efficiency, and so forth; the Bureau's program is designed to consider all of these factors.

Editor's Note: On the following page the authors have supplied their List of References. At this point we would like to interject the hope that the Bureau will keep the industry closely informed on its progress now that the decision was announced to install a 5000-kw prototype gas turbine at Muskingum River Plant.

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Low equivalent chromium alloys offer the best promise for reducing loss of impact strength in the high-temperature piping now used in steam-electric generating stations and processing plants, according to Ernest A. Sticha, chief research metallurgist, Edward Valves, Inc., speaking before the 22nd American Power Conference.

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Abstracts From the Technical Press—Abroad and Domestic

(Drawn from the Monthly Technical Bulletin, International Combustion, Ltd., London, W. C. 1)

Fuels: Sources, Properties and Preparation

Structure of Bituminous Coals: Evidence from Distribution of Hydrogen. P. H. Given. *Nature* 1959, **184** (Sept. 20) 980–1.

A type of structure has been found that fits the requirements of X-ray and infra-red studies and those of the elementary analysis: any one aromatic nucleus is linked to any other by two aliphatic linkages.

Abrasivity of Coals and the Resistance to Wear of Metals in Milling. N. V. Sokolov and V. P. Osokin. *Teploenergetika* 1959, (Nov.) 37–41 (in Russian).

A method is described for determining the abrasivity of coals and the resistance to wear of metals in pulverizing coals. The results are presented in tables and graphs.

Coal Handling at Waterside Plants. W. G. Hudson. *Power* 1959, **103** (Nov.) 68–9.

The coal handling plant at the T. H. Allen station is designed to move 2000 t/h, that at Gannon station for 500 t/h and that at Detroit Edison's River Rouge station for 2500 t/h. Brief details are given of each installation.

Coal Transport Plant of the Chalon-sur-Saône Power Station. W. Seidel. *Fördern und Heben* 1959, **9** (Oct.) 633–5 (in German).

The system is designed for stocking out 1000 t/h and reclaiming 500 t/h and to mix various fuels in prescribed proportions. The coal is emptied into a hopper from which two conveyors transport it to a central tower; there the coal is directed to either two conveyors to the storage, two conveyors to the mixing plant near the boiler house or to the screening and crushing plant. The coal is stored in a circular heap of 260 ft diam and 40 ft height by means of a combined spreading (belt conveyor) and reclaiming (bucket wheel) machine running on a circular rail, and then compacted by bulldozers.

Transport Problems of Low-grade Coal for Electricity Generation. E. Lilienfeld. *Fördern und Heben* 1959, **9** (Oct.) 636–8 (in German).

Comparisons are made of the cost of building small power stations at each colliery or a large central generating plant and the costs involved when transporting the coal by Federal railways, works-owned railway or aerial rope way.

A Safe Method of Storing Pulverized Coal at Trenton Channel. E. L. Embach. COMBUSTION 1959, **31** (Oct.) 45–7.

The boiler bunkers of Trenton Channel power station are supplied with pulverized coal from a central pulverizing plant and the coal is liable to ignite when stored for more than a few days. Tests carried out showed that the zone of greatest heat development was about 2 ft below the surface. The solution was found in excluding all air ingress through the coal feed line, air vent line to the furnace and coal gates at the bottom. It is recommended to install a thermometer and pressure indicator in the air space above the coal to watch for temperature rise and gas generation. In this way it is possible to keep coal in the bunkers for months without risk of autoignition.

Steam Generation and Power Production

Stresses in Hollow Cylinders Due to Asymmetrical Heat Generation. H. Kraus and G. Sonnemann. *J. Engng. Pwr.* 1959, **81** (Oct.) 449–54.

Equations are derived for the radial, tangential, shear and axial stresses in nuclear reactor vessels and thermal shields due to internal heat generation by the absorption of γ-radiation.

Hydrodynamics of Uniflow Boilers. A. A. Davidov and B. I. Sheynin. *Teploenergetika* 1959, (Nov.) 53–7 (in Russian).

Data are presented of the resistance of the steam-water cycle, loop pulsation, thermal sweep, distribution of steam-water mixture and its division into layers in uniflow boilers.

The Little Giant. D. A. Cassino. *Heat Engng.* 1959, **34** (July/Aug.) 56–61.

The packaged boiler is of the natural circulation, water-tube type with two drums and includes an economizer, furnace and interchangeable oil or coal firing front. Either a spreader stoker with a pulsating ash discharge grate or steam atomizing oil burners can be fitted. The duplex pumping and heating set supplies 300 gph No. 6 fuel oil at 220 F. Further included are a unit comprising a mechanical dust collector and i.d. fan, f.d. fan and drive, soot blowers, fly-ash reinjection system and combustion controls. The boiler is supplied to the site in 7 subassemblies. The boiler under test was rated at 30 klb/h but was able to generate up to 54 klb/h and its thermal efficiency exceeded 80 per cent. Change over from coal to oil or vice versa takes 4 men about 7h. Stoker-fired packaged units of 43, 50 and 63 klb/h at pressures up to 250 psi saturated can be supplied.

AGM-144-HS Foster Wheeler Packaged Boilers. J. Terry and W. B. Carpenter. *Heat Engng.* 1959, **34** (Sept./Oct.) 74–9.

Three boilers each rated at 39.5 klb/h at 500 psi and 650 F have been installed at Eddystone station to supply auxiliary steam for fuel oil heating, space heating, soot blowers, etc. The boilers are fired with No. 6 fuel oil, completely automatic in operation, and of D-type cross-section.

Chemical Cleaning of Benson Boilers. H. G. Heitmann. *Mitt. V.G.B.* No. 62 1959, (Oct.) 319–34 (in German).

A new method of acid cleaning of boilers has been worked out based on laboratory tests which uses much lower acid concentrations without inhibitors and thus makes possible the cleaning of the whole boiler system including austenitic superheaters and reheaters. The main features are the use of hydrazine (and ammonia) to obtain a pH above 5 in front of the pump and of hydrochloric or sulfuric acid (and fluoric and citric acid) behind the pump to obtain a pH of 3.5–4, a temperature of the cleaning medium of 100 C and relatively high circulation speeds. In addition, thorough flushing with condensate or dermineralized water and blowing with steam before and after cleaning is recommended. The treatment has resulted in a tube system free of rust, scale and welding beads, almost complete removal of silicic acid (sand) and the formation of a film of Fe_3O_4 on all tubes resistant to corrosion even for prolonged periods of shutdown.

Humidity Control During Boiler Erection. A. S. Miller. *Nucl. Engng.* 1959, **4** (Nov.) 404–5.

A portable air conditioning plant is described which has been developed for prevention of condensation inside nuclear boilers during erection on site. The air is heated in winter to 50–60 F

at 20 per cent rel. humidity and in summer to 65 F at 30 per cent r.h. and a flow rate of 1500–2500 cu ft/min.

Solid Fuel Firing

Problems of Coal and Air Distribution in Pulverised Coal Burners. R. Jung. *Mitt. V.G.B.* No. 62 1959, (Oct.) 371–82 (in German).

Investigations are reported aimed at improving the uniformity of pulverized coal distribution in branch lines and the design of a circular burner with adjustable flame length and uniform density of the coal and air at the burner mouth. The effect of elbows, splitters and baffles and of burner position has been studied. Finally, the effect of the parallel arrangement of slot-type and circular burners on ignition and the mixing process is discussed on the basis of model tests.

A Circular Burner for Different Fuels. H. Ullrich. *B.W.K.* 1959, **11** (Oct.) 465–7 (in German).

The main improvements in this burner for the separate or combined firing of oil and coal is the inclusion of a ring carrying guide vanes moving axially in a conically shaped housing with which the angle of swirl of the secondary air can be altered by varying the proportion of secondary air with swirl to that without. In a modification of the burner the pulverized coal-air mixture can also be given different swirls by means of adjustable guide vanes at the entry into the burner. It is possible by these means to obtain optimum mixing of fuel and air at the burner mouth, reduce ignition time and vary the flame length to suit the properties of the fuel and the furnace design. Experience with these burners in a boiler fired wih bituminous and brown coal and oil has been very satisfactory.

Furnaces and Combustion

Excess Air and Combustion Efficiency in Incomplete Combustion. F. Schuster. *BrennstChemie* 1959, **40** (Oct.) 326–9 (in German).

A method has been worked out for calculating combustion efficiency and excess air when combustion is incomplete. The method is applicable to all fuels and combustion conditions.

Water-Side Corrosion and Water Treatment

Pilot-Plant Water Studies for Eddystone Station. F. N. Megahan. *A.S.M.E. Preprint* No. 59-A-260 1959, (Dec.) 4 pp.

After prolonged tests with various anion resins for feedwater treatment a two-bed, mixed-bed system was chosen to obtain the quality required for the supercritical pressure unit at Eddystone station. In all units 8.5 per cent cross-linked cation resin and non-porous Type I anion resin will be used which should give an effluent from the mixed bed of 0.07 μ mho and 5 ppb SiO_2.

Water-Treatment, Corrosion, and Internal-Deposit Studies for Eddystone. R. C. Ulmer, H. A. Grabowski and R. C. Patterson. *A.S.M.E. Preprint* No. 59-A-147 1959, (Dec.) 8 pp.

The extensive tests carried out to determine feed water treatment for the 5000-psi 1200 F Eddystone unit are described concerning deposition of salts, corrosion of steel, copper and iron pickup and deposition on tube walls. Complete demineralization of the feedwater and bypass demineralization of the condensate, addition of hydrazine at a rate of 10 ppb and addition of ammonia to maintain the pH at 8.5–9.5 are considered essential to prevent failures.

Gas-Side Corrosion and Deposits

Experience with Dolomite as Additive in Oil-fired Boilers. H. Ulrich. *Energie* 1959, **11** (Oct.) 474–6 (in German).

A German refinery has undertaken research into the injection of dolomite into oil-fired boilers on their own boiler plant. In a new boiler dolomite was not used at first and in consequence its output fell by 15% over 3000 h, due to deposit formation on the economizer and air preheater. After injection of dolomite (not mixed with the oil) ground to 14.2 per cent residue on No. 240 sieve and 4.5 per cent residue on No. 170 sieve at a rate of three times the ash content of the oil or about 3.3 lb/t of oil the deposits formed could easily be removed by soot blowers or brushing and no new corrosion was found. In addition, very hard deposits on the superheater tubes containing a high percentage of V_2O_5 encountered previously were no longer formed.

Flue Gas, Ash and Dust

Determination of the Dew Point of Flue Gases from the Evaporation Equilibrium of the System Water-Sulfuric Acid. R. Haase and M. Rehse. *Mitt. V.G.B.* No. 62 1959, (Oct.) 367–71 (in German).

From the measurements of the evaporation equilibrium graphs of dew point as a function of partial pressure of H_2SO_4 for different values of partial pressure of H_2O have been obtained. Their application to the plotting of

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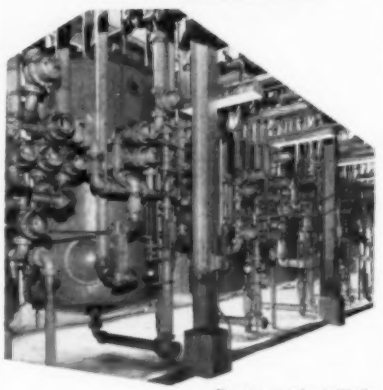

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curves of dew point of flue gases of fuel oils as a function of their S content and its conversion into SO_3 is shown. Similar measurements for the system H_2O-H_2SO_4-Cl are in progress.

Fly Ash Utilization in the U.S.A. H. J. Rose and H. H. Russell. *Mitt. V.G.B.* No. 62 1959, (Oct.) 335–44 (in German).

The main fields of utilization of fly ash reviewed are: 1. In Portland cement concrete and mortar for road building and civil engineering; 2. As mineral filler in bituminous asphalt and tar roads and surfaces; 3. In mixtures with lime and soil for soil stabilization. A large number of these applications are described and illustrated.

The Utilization of Fly Ash in France. A. Jarrige. *Mitt. V.G.B.* No. 62 1959, (Oct.) 345–55 (in German).

In France fly ash is used in road building, concrete and as addition to Portland cement. France is the only country so far where fly ash (20 per cent) is regularly mixed with Portland cement in the cement works; in 1958 about 290,000 t of fly ash were thus utilized. A French mine produces building bricks containing 25 per cent fly ash (unground) or 35 per cent fly ash (ground). Results of laboratory and pilot-scale studies are described.

Fly Ash + Slag + Gypsum + Lime = Cements. J. Pochebonne. *Flamme et Thermique* 1959, **10** (Aug./Sept.) 13–20 (in French).

Laboratory tests with various mixtures are described and the results discussed. A mixture containing Portland cement, 49 per cent fly ash, lime and gypsum has proved entirely satisfactory and is proposed to alleviate the acute shortage of cement for concrete.

Experience in Utilization and Sale of Granulated Slag in a West-German Power Station. E. Goecke. *Mitt. V.G.B.* No. 62 1959, (Oct.) 356–8 (in German).

The slag is used in foundations of houses as a lower layer of 2–4 in. thickness on which a concrete base is laid with a thickness of 2 in., as filler in cable and pipe ducts mixed with sand in a ratio of 1:1 and well consolidated, for drainage of soils of sewage plants, air and sports fields, gardens and roads. About 90 per cent of the slag produced is now sold and utilized.

Measurements of Dust Deposition in Essen from November 1955 to February 1957. K. Schwarz, T. Gilbert, E. Ratzki and M. Diem. *B.W.K.* 1959, **11** (Oct.) 483–7 (in German).

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means of 600 sticky foils although simultaneous comparative measurements with two other collecting methods showed that sticky foils tended to give low results when the deposition was heavy. The local distributions as a function of wind direction and weather conditions is shown in 3 graphs. The highest depositions of over 100 g/m²/30 days occurred with North wind which carried with it large amounts of dust from the industrial towns to the North of Essen. In the northern part of Essen the dust deposition averages 50 g/m²/30 days, in the southern part it is less than 30 g/m²/30 days.

Flow Induced Noise in Heat Exchangers. A. A. Putnam. *J. Engng. Pwr.* 1959, **81** (Oct.) 417–22.

Types of vibrations involved and measures used to reduce these are described.

Problems of Improving Steel Shot Installations for Cleaning Heating Surfaces from Ash Deposits. N. V. Kouznetzov, G. I. Louzhnov, A. I. Krasovitzky, B. B. Soloviev and K. M. Taldikin. *Teploenergetika* 1959, (Nov.) 8–11 (in Russian).

Various improvements introduced recently and their effectiveness are described.

Power Generation and Power Plant

Review: The Work of the First Five Years of the National Industrial Fuel Efficiency Service. Anon. *J. Inst. Fuel* 1959, **32** (Nov.) 556–61.

The expansion of the activities of N.I.F.E.S. during the first 5 years of its operation is reviewed. A total of 3499 factories are being served involving 12,000 units. On average, a fuel saving of 20.8 per cent has been achieved. Details are presented of economies achieved in the cotton finishing industries, paper, printing and allied trades, and metallurgical furnaces. The work of N.I.F.E.S. is to be extended to other industrial processes to improve productivity and reduce heat consumption.

Magnetohydrodynamics — Future Power Process? P. Sporn and A. Kantrowitz. *Power* 1959, **103** (Nov.) 62–5.

In this process electric energy is directly generated by a highly heated gas flowing through a magnetic field and recent research makes it appear possible to apply this process to large-scale power generation. A power plant cycle is proposed which would have a heat rate of 6200 Btu/kWh when generating 462 MW net output. The main parts of the proposed plant

are described and studies still to be carried out are indicated.

A New Performance Criterion for Steam Turbine Regenerative Cycles. J. K. Salisbury. *J. Engng. Pwr.* 1959, **81** (Oct.) 389–402.

The flow-weighted average extraction enthalpy embodying in a single variable all the effects of extracting steam for feedwater heating permits quick and direct estimation of the effect of any cycle change on heat rate and the improvement to be realized by regeneration.

The 100 MW Unit in the Hattingen Power Station. J. Schubert. *Electwirtsch.* 1959, **58** (Nov. 5) 737–43 (in German).

The unit consists of a Benson boiler, rated at 350 t/h at 260 atü and 605 C with reheat to 530 C, with a polygonal slagging furnace. The first pass (upward) is entirely constituted of radiant wall surfaces, the second pass (downward) contains tube platen superheater surfaces, the convection surfaces start in the third pass with a flue gas entry temperature of 950 C. The turbine is divided into 4 sections with 10 stages of feedwater preheating to 303 C. The feedwater is treated in parallel cation and mixed bed demineralizers. The turbines for the feed pumps receive their steam from the 6th extraction stage. The steels used for the boiler, pipe lines and turbine are detailed. The calculated net heat rate is 2109 kcal/kWh or a thermal efficiency of 40.7 per cent. A special starting system is used until the boiler output has reached 90 t/h; full output is reached after 6–7h when starting from cold.

Power Station Unit Installations for 600 C Superheated Steam Temperature. The 80 MW Unit in the Neuhof Power Station. E. Strange. *Electwirtsch.* 1959, **58** (Nov. 5) 729–36 (in German).

This unit was the first for a superheated steam temperature of 600 C erected in a public power station. The Benson boiler is rated at 250 t/h at 155/206 atü and 605/615 C with reheat to 525 C, has $2^1/_2$ passes and an octagonal furnace with dry ash removal. Four mills of 8.5 t/h capacity supply the corner burners, the primary air constituting 15 per cent of the total. The net heat rate optimum is 2250 kcal/kWh. The unit was started 60 times in this period after shutdowns of 5 to 48 h. During starting a temperature gradient of 6 C/min up to 480 C and of 3 C/min above that has been fixed to reduce thermal shock in the austenitic steel; to reach temperatures above the saturated as quickly as possible starting is carried

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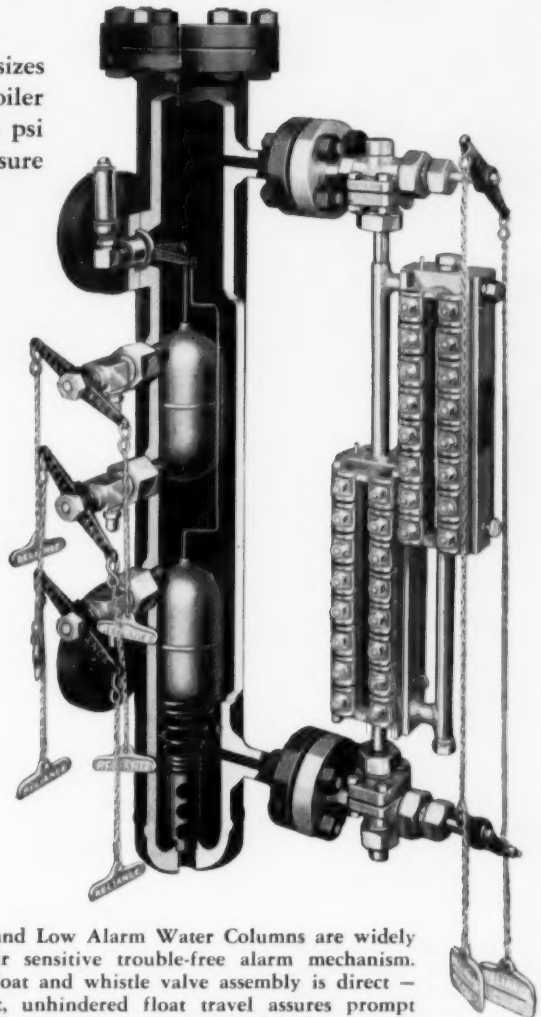

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out without pressure. Starting from cold takes 4–4.5 h, after 48 h shutdown about 3 h, after 5–8 h shutdown 2.5 h. The average net heat rate has been 2320 kcal/kWh including 6.5 per cent consumption of auxiliaries and a boiler efficiency of 92.5%. The feedwater is not treated with ammonia or hydrazine and has a pH of 7. Light deposits of silicic acid form.

Steam Generator of 650 t/h for 200 MW Units. T. Geissler. *B.W.K.* 1959, **11** (Oct.) 463–5 (in German).

The Polish power station at Turow will contain 6 units each consisting of a German boiler rated at 1450 klb/h at 2000 psi and 1005/1000 F and a 200 MW Russian turbogenerator. The furnace is octagonal, has a volume of 17,000 cu ft (22,600 cu ft including the space for the tube-platen superheater) and contains 8 corner burners served by eight beater mills (one reserve) each of 36/45 t/h output. The fuel is brown coal with 45–50 per cent moisture, 20–25 per cent ash, 45 per cent V.M. and a net C.V. of 3240 Btu/lb. There are two separate water-steam circuits, i.e., 2 economizers, 2 steam drums and 2 primary and 2 secondary superheaters. The steam is first reheated in 2 heat exchangers (outside the boiler) by superheated steam and finally in 2 conection reheaters by flue gas. The superheated steam temperature is controlled by 3 spray desuperheaters, the reheated steam temperature by varying the temperature of the superheated steam. The 3 parallel Ljungstrom air preheaters heat the air to 520 F and cool the flue gas to 320 F; steam heated air preheaters are used additionally when bunker C oil is fired (ignition torches and low-load support burners). The turbogenerator is of the single-shaft type with 2 parallel condensers and requires 12 h heating up until it can be connected to the grid. There are 4 l-p stages, main deaerator and 3 h-p stages of feedwater preheating.

The new Zolling-Anglberg Power Station of the Isar-Amperwerke A.G. Munich. II. W. Fadinger and K. Kohler. *Tech. Überw.* 1959, **11** (Oct.) 365–72 (in German).

The methods used for carrying out the tests on the boiler and turbine are described and the results tabulated. The thermal efficiency of the boiler was 93.1 per cent at normal and 91.7 per cent at m.c.r. and the thermal efficiency of the whole unit 33.35 per cent at an output of 40 MW and 30.65 per cent at 16 MW or 10200 Btu/kWh and 11,100 Btu/kWh, resp.

The Klöckner Power Station at Castrop-Rauxel. A. Brackel and H. Emonts. *Siemens Zschr.* 1959, **33** (Sept.) 542–556 (in German).

The boiler plant, turbo-generating unit and feed-heating plant form a single block, the boiler plant consisting of two half-load Benson boilers. The turbine is designed for an inlet pressure of 2560 psig and a live steam and reheat temperature of 520 C. The maximum continuous output is 120 MW. A description is given of the construction and equipment of the power station.

From C.E.G.B. Digest 1959, **11** (Oct. 24) 2807.

Trawsfynydd Nuclear Power Station. 1—Engineering Design. J. W. Ashley. *Nucl. Pwr.* 1959, **4** (Nov.) 90–4.

Design details of this 500 MW (e) net nuclear power station include: 1. Core; 2. Pressure vessel; 3. Fuel Elements; 4. Charge/discharge; 5. Reactivity control; 6. Boilers; 7. Gas flow; 8. Turbogenerators; 9. Station Control.

Trawsfynydd. 2—Technical Calculations. S. A. Young. *Nucl. Pwr.* 1959, **4** (Nov.) 95–7.

The calculations of reactor performance, control conditions, flux stability, and shielding and radiological safety are set out.

Trawsfynydd. 3—Civil Engineering. D. H. New. *Nucl. Pwr.* 1959, **4** (Nov.) 97–9.

The considerations are outlined on which the civil engineering design has been based.

Materials and Manufacturing Processes

The Corrosion Resistance of Magnesium and Its Alloys in Nuclear Engineering Environments. P. E. Gallant. *Corros. Prev. and Contr.* 1959, **6** (Oct.) 42–5.

A review of the literature under the headings: 1. Oxidation behavior of magnesium; 2. Oxidation behavior of magnesium alloys; 3. Alloy development; 4. Metallurgical behavior; 5. Cooling pond corrosion; 6. Current work; 7. Future prospects.

Progress in Stainless and Heat-Resisting Steels. J. Lomas. *Engng. Boil. Ho. Rev.* 1959, **74** (Oct.) 318–19.

A review of recent literature in the field of corrosion and high-temperature resistant steels, welding techniques and electrodes, abrasion resistant steels and the production of stainless steel by extrusion for conventional and nuclear power stations.

The Effect of Alloying Mild Steel upon Its Resistance to Stress-Corrosion Cracking. R. N. Parkins and A.

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Brown. *J. Iron & Steel Inst.* 1959, **193** (Sept.) 45–7.

The resistance to stress-corrosion cracking of mild steels could be improved by addition to Cr and of up to 1 per cent Al.

The Influence of Chromium Diffusion Upon the Thermal Oxidation Properties of Steels and of Nickel- and Cobalt-Base Alloys. R. L. Samuel and T. P. Hoar. *Metallurgia* 1959, **60** (Sept.) 75–80.

The increased resistance to oxidation of steels and Ni and Co base alloys by the surface treatment with Cr is demonstrated. Chromising may also alter the nature of the oxidation.

Results and Problems of Development of Graphite for Reactors in Germany. E. Fitzer, M. Beutell, E. Nedopil and K. W. F. Etzel. *Atomkernenergie* 1959, **4** (Nov.) 449–55 (in German).

This first part deals with the production of graphite of 99.999 per cent pure carbon and presents data of electrical and thermal conductivity, thermal and volumetric expansion.

Fabricator Scores Breakthrough in Joining Titanium Clad Steel. Anon. *Steel* 1959, **145** (Oct. 19) 152–3.

The mild steel plate of 0.5 in. thickness and titanium cladding plate of 0.078 in. thickness were bonded together by a brazing metal under vacuum. The welds between plates and fittings were made by an intermediary silver inlay with a titanium cover strap.

Welded and Rolled Joints in High-Pressure Preheaters. H. Haferkamp *Mitt. V.G.B.* No. 62 1959, (Oct.) 365–7 (in German).

In rolled and welded joints of tubes in tube plates for high-pressure feedwater preheaters leakage occurred when the welding was carried out by the argon arc process but not if oxyacetylene welding was used. In the former the weld pool is small and solidifies so quickly that gas bubbles from evaporating moisture are trapped, in the latter the pool is larger and its solidification takes longer so that the gas bubbles can escape.

The Application of Dimensional Analysis to the Determination of the Maximum Temperature Difference in Cylindrical Fuel Elements. W. Kattwinkel. *Atomkernenergie* 1959, **4** (Sept.), 356–9 (in German).

The analysis shows that a fuel element should be so designed that the temperature difference becomes a minimum and the resultant thermal stresses remain within the given limits.

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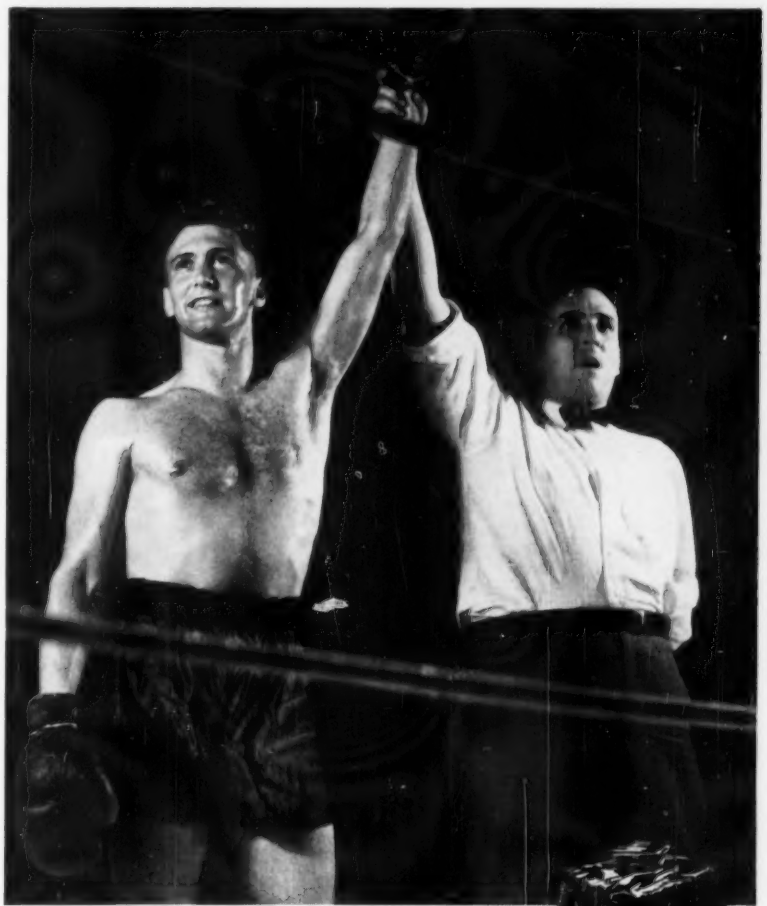

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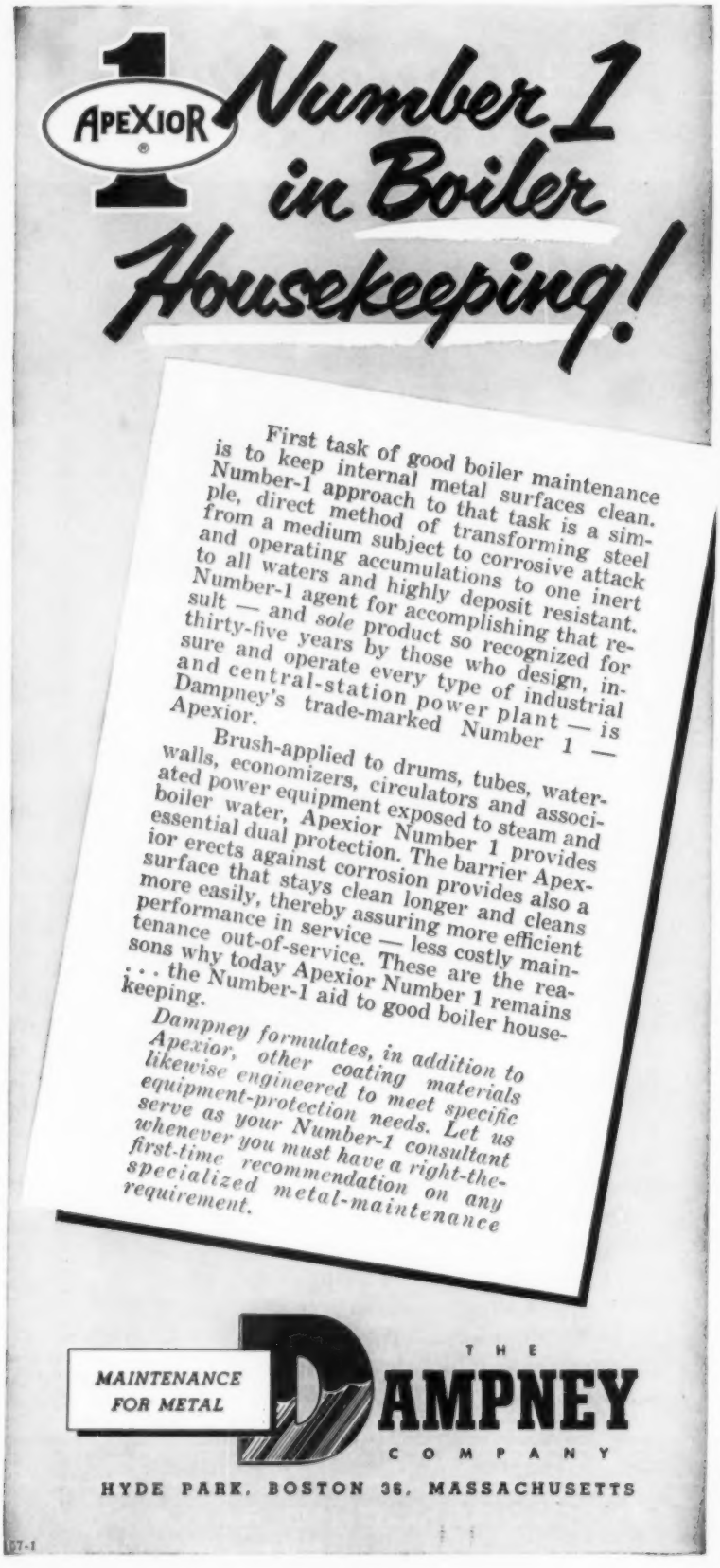
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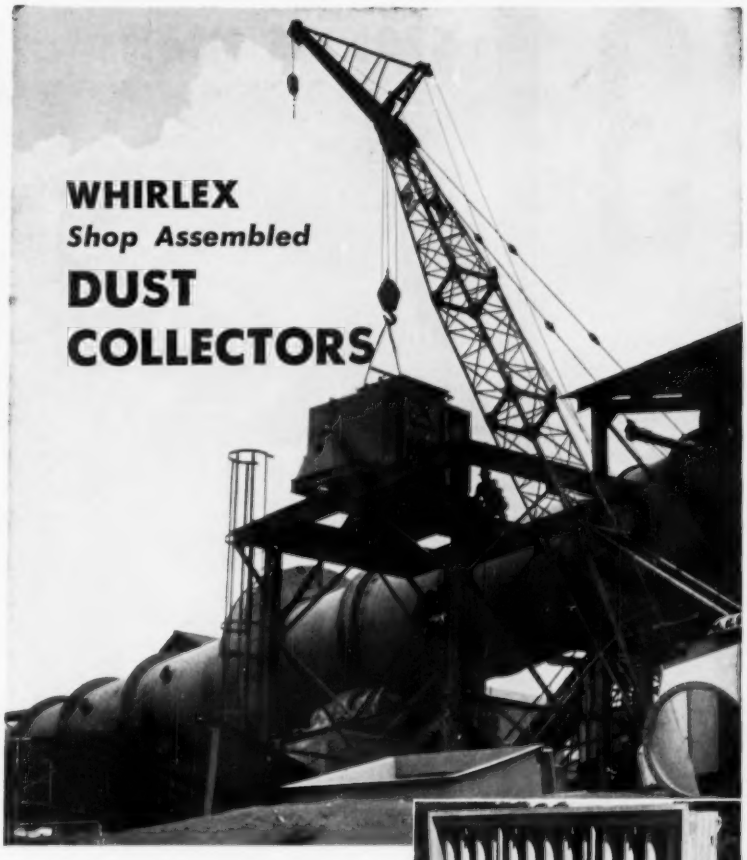

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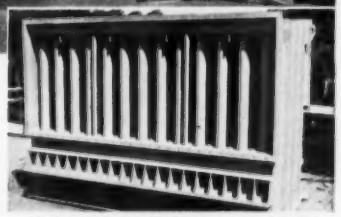

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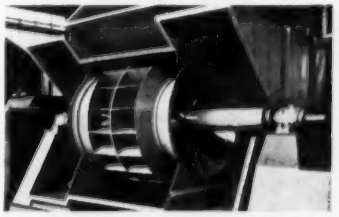

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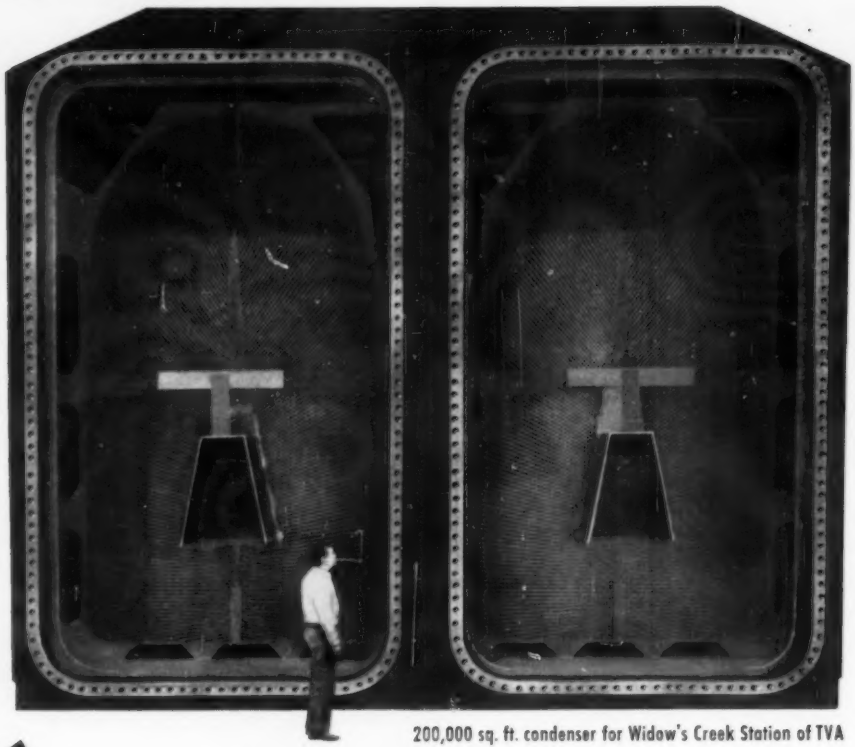

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